ROBERT A. SKIDMAN

FAO Fisheries Technical Paper No. 200 FIRM/T200(En)

Pacific Islands Science Center
Honolulu, Hawaii 96822-2396

STATE OF SELECTED STOCKS OF TUNA AND BILLFISH IN THE PACIFIC AND INDIAN OCEANS

LIBRARY
Pacific Islands Fisheries Science Center
2570 Dole St.
Honolulu, Hawaii 96822-2396

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

STATE OF SELECTED STOCKS OF TUNA AND BILLFISH IN THE PACIFIC AND INDIAN OCEANS

Summary Report of the
Workshop on the Assessment of Selected Tunas
and Billfish Stocks in the Pacific and Indian Oceans

Organized by the Honolulu Laboratory, Southwest Fisheries
Center, National Marine Fisheries Service and the
Far Seas Fisheries Research Laboratory of the
Fisheries Agency of Japan

Shimizu, Japan, 13-22 June 1979

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Rome 1980

Les appellations employées dans cette publication et la présentation des données qui y figurent n'impliquent de la part de l'Organisation des Nations Unies pour l'alimentation et l'agriculture aucune prise de position quant au statut juridique des pays, territoires, villes ou zones, ou de leurs autorités, ni quant au tracé de leurs frontières ou limites.

M-43
ISBN 92-5-101003-X

Reproduction interdite, en tout ou en partie, par quelque procédé que ce soit, sans l'autorisation écrite de l'Organisation des Nations Unies pour l'alimentation et l'agriculture, seule détentrice des droits. Adresser une demande motivée au Directeur de la Division des publications, Organisation des Nations Unies pour l'alimentation et l'agriculture, Via delle Terme di Caracalla, 00100 Rome, Italie, en indiquant les passages ou illustrations en cause.

© FAO 1980

PREPARATION OF THIS PAPER

This report summarizes the present state of knowledge of most of the stocks of tunas in the Pacific and Indian Oceans and billfishes in the Indian Ocean, as determined at the Workshop on the Assessment of Selected Tuna and Billfish Stocks in the Pacific and Indian Oceans held at the Far Seas Fisheries Research Laboratory (FSFRL) in Shimizu, Japan, from 13-22 June 1979. The Workshop was organized and co-hosted by the Honolulu Laboratory, Southwest Fisheries Center, National Marine Fisheries Service, and FSFRL, Fisheries Agency of Japan. This document was prepared by participants in the Workshop. Considerable editorial assistance was provided by Dr. Robert E. Kearney of the South Pacific Commission, Noumea, New Caledonia, and by Dr. Jerry A. Wetherall, Mr. Howard O. Yoshida, and the support staff of the Honolulu Laboratory.

ACKNOWLEDGEMENT

Support for publication of this paper was provided by the FAO/UNDP Project on Tuna Management in the Indian and Pacific Oceans (INT/79/026/A/01/12).

Distribution:

FAO Fisheries Department
FAO Regional Fishery Officers
Selector SM
ACMRR
Members of the IOFC/IPFC Tuna Management Committees

For bibliographic purposes this document should be cited as follows:

National Marine Fisheries Service, Southwest
1980 Fisheries Center, Honolulu Laboratory and the Far Seas Fisheries Research Laboratory of the Fisheries Agency of Japan. State of selected stocks of tuna and billfish in the Pacific and Indian oceans. Summary report of the Workshop on the assessment of selected tunas and billfish stocks in the Pacific and Indian oceans. Organized by the Honolulu Laboratory, Southwest Fisheries Center, National Fisheries Service and the Far Seas Fisheries Research Laboratory of the Fisheries Agency of Japan. Shimizu, Japan, 13-22 June, 1979. FAO Fish.Tech.Pap., (200):89 p.

Abstract

Available historical fishery information is summarized for the large tunas of major market importance. The information is current to 1977 in most cases and 1978 in some. Billfish fishery information is similarly reviewed for the Indian Ocean fisheries. Stock structure information and current research activities are also reviewed. Population parameters, regulations and/or recommendations are discussed. Skipjack tuna fishery information is not discussed.

CONTENTS

		Page
1.	INTRODUCTION	1
2.	EXECUTIVE SUMMARY	1
2.1	Species Considered	1
2.2	Statistics and Other Data	1
2.3	Stock Appraisals	2
2.3.1	Pacific yellowfin tuna	2
2.3.2	Pacific northern bluefin tuna	2
2.3.3	Pacific bigeye tuna	2
2.3.4	South Pacific albacore	2
2.3.5	Southern bluefin tuna	3
2.3.6	Indian Ocean yellowfin tuna	3
2.3.7	Indian Ocean bigeye tuna	3
2.3.8	Indian Ocean albacore	3
2.3.9	Indian Ocean billfishes	3
2.4	General Problems in Stock Assessment	4
2.4.1	Effort	4
2.4.2	Age, growth, and mortality	4
2.4.3	Assessment of the effect of fishing	4
2.5	Estimates of Total Catch by Species	4
3.	RAPPORTEURS' REPORTS	7
3.1	Statistics and Other Data	7
3.1.1	General remarks	7
3.1.2	Problems of different types of fisheries	7
3.1.3	Changes in the Law of the Sea	8
3.1.4	Priorities	9
3.1.5	Action needed	9
3.2	Pacific Yellowfin Tuna	10
3.2.1	Review of current research	10
3.2.2	Review of fishery data	15
3.2.3	Stock structure	19
3.2.4	Population parameters	20
3.2.5	Status of stocks	20
3.2.6	Recommendations	24
3.3	Pacific Northern Bluefin Tuna	24
3.3.1	Review of current research	26
3.3.2	Review of fishery data	26
3.3.3	Stock structure	26
3.3.4	Population parameters	27
3.3.5	Status of stocks	29
3.3.6	Effects of regulation	29
3.3.7	Recommendations	29
3.4	Pacific Bigeye Tuna	31
3.4.1	Review of current research	31
3.4.2	Review of fishery data	31
3.4.3	Stock structure	36
3.4.4	Population parameters	36

	Page
3.4.5 Status of stocks	38
3.4.6 Effects of regulations	39
3.4.7 Recommendations	41
3.5. South Pacific Albacore	41
3.5.1 Review of current research	41
3.5.2 Review of fishery data	41
3.5.3 Stock structure	43
3.5.4 Population parameters	43
3.5.5 Status of stocks	44
3.5.6 Recommendations	45
3.6 Southern Bluefin Tuna	46
3.6.1 Review of current research	46
3.6.2 Review of fishery data	46
3.6.3 Stock structure	50
3.6.4 Population parameters	50
3.6.5 Status of stocks	50
3.6.6 Effects of regulations	51
3.6.7 Recommendations	51
3.7 Indian Ocean Yellowfin Tuna	53
3.7.1 Review of current research	54
3.7.2 Review of fishery data	54
3.7.3 Stock structure	57
3.7.4 Population parameters	57
3.7.5 Status of stocks	58
3.7.6 Recommendations	60
3.8 Indian Ocean Bigeye Tuna	60
3.8.1 Review of current research	60
3.8.2 Review of fishery data	61
3.8.3 Stock structure	63
3.8.4 Population parameters	64
3.8.5 Status of stocks	64
3.8.6 Effects of regulations	64
3.8.7 Recommendations	65
3.9 Indian Ocean Albacore	66
3.9.1 Review of current research	66
3.9.2 Review of fishery data	67
3.9.3 Stock structure	68
3.9.4 Population parameters	68
3.9.5 Status of stocks	68
3.9.6 Effects of regulations	68
3.9.7 Recommendations	69
3.10 Indian Ocean Billfishes	69
3.10.1 Review of current research	69
3.10.2 Review of fishery data	72
3.10.3 Stock structure	73
3.10.4 Population parameters	74
3.10.5 Status of stocks	76
3.10.6 Recommendations	76
3.11 General Problems in Stock Assessment	76
3.11.1 Effort	77
3.11.2 Age, growth, and mortality	79

Page

3.11.3 Assessment of the effect of fishing 79

4. LITERATURE CITED 82

APPENDICES

1. Agenda 85
2. List of Participants 86
3. Rapporteurs 87
4. List of Background Papers 88

1. INTRODUCTION

The Workshop on the Assessment of Selected Tuna and Billfish Stocks in the Pacific and Indian Oceans was held at the Far Seas Fisheries Research Laboratory (FSFRL), Fisheries Agency of Japan, in Shimizu, Japan, during 13-22 June 1979. The objectives of the workshop were (1) to review the status of stocks of selected tuna and billfish resources in the Pacific and Indian Oceans and (2) to identify future research needs to improve the understanding and assessment of these resources. Dr. Shoji Ueyanagi of FSFRL and Mr. Richard S. Shomura of the Southwest Fisheries Center, National Marine Fisheries Service, Honolulu, Hawaii, were co-chairmen. Dr. Y. Fukuda, Director of the FSFRL opened the workshop by welcoming the participants to the Laboratory and to the city of Shimizu.

This report summarizes the highlights of the workshop and includes detailed rapporteurs' reports covering the stocks evaluated. The workshop agenda is given in Appendix 1. The participants in the workshop are listed in Appendix 2 and the rapporteurs for the various sections are listed in Appendix 3. The background papers submitted to the workshop are listed in Appendix 4.

2. EXECUTIVE SUMMARY

2.1 Species Considered

The workshop participants reviewed the status of most tuna stocks in the Pacific and Indian Oceans, including the yellowfin tuna, Thunnus albacares, bigeye tuna, T. obesus, northern bluefin tuna, T. thynnus, southern bluefin tuna, T. maccoyii, and albacore, T. alalunga. Of the Pacific albacore stocks, only the South Pacific stock was covered, since the North Pacific albacore resource is being monitored as part of a continuing informal arrangement between the Southwest Fisheries Center of the National Marine Fisheries Service and the Far Seas Fisheries Research Laboratory (Wetherall[1]). Skipjack tuna, Katsuwonus pelamis, was not discussed.

In addition to the tunas, the group reviewed the status of billfishes in the Indian Ocean, which are caught primarily by longline gear incidentally to the harvest of tunas. The billfishes include the blue marlin, Makaira nigricans,[2] striped marlin, Tetrapturus audax, black marlin, M. indica, swordfish, Xiphias gladius, sailfish, Istiophorus platypterus, and shortbill spearfish, T. angustirostris. Billfishes of the Pacific were the subject of a workshop held in 1977 in Honolulu, Hawaii (Shomura, 1980).

2.2 Statistics and Other Data

The workshop reviewed the quality of tuna fishery data in various national and international institutions. In some tuna fisheries of the Pacific and the Indian Oceans, the data necessary for stock assessment analyses, including total catches, corresponding fishing effort, size composition, and related biological data, are not available. Common problems and problems peculiar to various fisheries were identified for small-scale or artisanal fisheries, local or medium-range industrial-scale fisheries, long-range fisheries landing in home ports, "transshipment" fisheries, joint ventures, and sport fisheries. These are discussed in detail in Section 3.1.

The impact of extended fishery jurisdictions by coastal states on the quality and availability of tuna fishery data was discussed. The short-term result of additional fishery controls has been a reduction in the quality of fishery data in some areas although

---

[1]Wetherall, J.A. (Ed.), Report of the Third North Pacific Albacore Workshop, Honolulu, 1979 Hawaii, 13-14 September 1978 (Rev.). Southwest Fish.Cent.Admin.Rep. 25H, 1978, Natl.Mar.Fish.Serv., NOAA, Honolulu, Hawaii, 11 p. (Unpubl. rep.)

[2]There is some controversy on the scientific name of the blue marlin. Nakamura et al. (1968) support the view that the Indo-Pacific blue marlin should be designated as M. mazara.

ultimately the changes should result in more complete reporting of catch and effort. First priority should be given to statistics of total catch but data on fishing effort, size composition, and detailed position of capture are also essential for stock and fishery assessments. The group strongly recommended that countries landing large quantities of tuna but collecting inadequate fishery statistics take action to improve their data collection. Although national data collection efforts are essential, tuna fishery statistics for the western Pacific and Indian Ocean cannot be effectively organized, disseminated, and evaluated until one or more regional institutions are organized to accomplish these tasks. Where overlaps in areas of responsibility occur, there will be a need for careful coordination between various regional and national institutions handling data.

2.3 Stock Appraisals

2.3.1 Pacific yellowfin tuna

The Pacific yellowfin tuna resource is assumed to be composed of east and west stocks with the possibility of a third stock in the central Pacific. Total Pacific catches of yellowfin tuna ranged from 103,200 to 145,900 metric tons (MT) annually during 1952-59 and from 158,700 to 220,200 MT during 1960-69. From 1970 to 1977 they ranged between 200,100 and 417,000 MT. The catch per unit effort (CPUE) in most areas fell sharply following the initial few years of fishing and then gradually declined further as effort continued to increase.

A production model analysis of eastern tropical Pacific (ETP) yellowfin tuna estimated maximum sustainable yield (MSY) to be about 159,000 MT within the Commission's Yellowfin Regulatory Area (CYRA) of the Inter-American Tropical Tuna Commission (IATTC). In the ETP yellowfin tuna fishery, recent catch levels have exceeded the estimated MSY. A continuation of the IATTC's experimental overfishing program is useful in determining whether the estimate of MSY is accurate, or whether further increases in catch can be sustained.

Production model analyses have not been done for the surface and longline fisheries in the western and central Pacific. However, an analysis of the Pacific-wide longline fishery provided an MSY estimate of around 80,000 to 90,000 MT and suggested that increases in longline effort above present levels would not increase the catch appreciably. While there is a possibility that the overall yield of central and western Pacific yellowfin tuna could be increased by expanded surface fisheries, no analyses of this prospect have been done.

2.3.2 Pacific northern bluefin tuna

The northern bluefin tuna resource in the Pacific is believed to be composed of a single stock. The total annual catch of northern bluefin tuna in the North Pacific ranged from about 8,600 to about 33,500 MT between 1952 and 1977. The available data did not allow any estimate of MSY.

2.3.3 Pacific bigeye tuna

The stock structure of bigeye tuna in the Pacific is unknown but a single stock was assumed for purposes of resource assessment. The total annual catch of bigeye tuna by all gears rose from about 29,600 MT in 1952 to 149,800 MT in 1963, then declined to 73,600 MT in 1968, and rose to 141,900 MT in 1976. The Japanese longline CPUE ranged between 507 and 616 MT/10^6 hooks from 1957 to 1961 and declined to 213 MT/10^6 hooks in 1977.

The present condition of the bigeye tuna resource has not been accurately assessed. Assuming a single stock, a production model analysis predicted an MSY for the longline fishery in the range of 100,700 to 106,700 MT but this estimate is considered unreliable. The likelihood that higher overall catches can be sustained should be evaluated.

2.3.4 South Pacific albacore

The South Pacific albacore resource is assumed to be composed of a single unit stock. The catch of albacore in the South Pacific from 1952 to 1977 ranged between 210 and 48,800

MT. An annual abundance index for 1962-77 computed from Japanese, Korean, and Taiwan longline statistics declined steadily from 1962 to a low in 1975 and increased in 1976 and 1977. The generalized production model analysis using this index predicted an MSY between 33,000 and 36,000 MT for the longline fishery. The analysis also indicated that no increase in yield can be expected from an increase in longline effort above the 1977 level. The current fishing levels in the South Pacific do not appear to be seriously affecting the stock. The potential for increasing total yield through expanded surface fishing should be studied.

2.3.5 Southern bluefin tuna

The southern bluefin tuna resource is believed to be composed of one stock. The annual catch of southern bluefin tuna in the Japanese longline fishery peaked in 1961 and fluctuated in a generally downward trend thereafter. The Australian surface catch increased from 1953 through 1969, trended downward through 1973, and then rose again. The CPUE in most areas where the Japanese longliners fish either started out at high levels and steadily declined or increased for several years before declining. No MSY estimate is available for southern bluefin tuna. However, it appears that increasing the fishing effort would not result in substantially increased catches.

2.3.6 Indian Ocean yellowfin tuna

The Indian Ocean yellowfin tuna resource is believed to be composed of either two stocks (east and west of about long. 100°E) or a single stock. The total catch of Indian Ocean yellowfin tuna by surface and longline gears in recent years has ranged from 41,200 to 70,500 MT. The largest catch of 88,100 MT was made in 1968. It is believed that the MSY for Indian Ocean yellowfin tuna in the longline fishery of Taiwan, Korea, and Japan is somewhere between 40,000 and 60,000 MT but this estimate is not very reliable. Further, the potential of increasing total yield by expanding surface fisheries has not been evaluated.

2.3.7 Indian Ocean bigeye tuna

It is assumed that there is only one stock of bigeye tuna in the Indian Ocean. The total annual catch of bigeye tuna ranged from 1,500 to 39,700 MT between 1952 and 1977. Japanese longline CPUE declined from around 0.7 fish/100 hooks in 1957-58 to around 0.4 fish/100 hooks in 1976 and then increased to over 0.9 fish/100 hooks in 1977. A production model analysis did not provide a reliable estimate of MSY but suggested that further increases in longline fishing effort would increase the total catch.

2.3.8 Indian Ocean albacore

It was assumed that there is a single stock of albacore in the Indian Ocean. The catch of albacore ranged from 67 to 28,200 MT between 1952 and 1977 (Table 2). A production model analysis estimated MSY for the longline fisheries of Korea, Taiwan, and Japan to be between 15,000 and 20,000 MT. There appears to be no reason for concern over the future of the Indian Ocean albacore, but increase in longline effort are unlikely to increase the catch.

2.3.9 Indian Ocean billfishes

There is little evidence to refute either single or multiple stock hypotheses for Indian Ocean billfishes. The historical record of billfish catches in the Indian Ocean is incomplete; however, Japanese and Taiwan catches of most species reached high levels in the 1960's and declined thereafter. The CPUE for blue marlin, striped marlin, and black marlin declined noticeably over the 1952-76 period in the Japanese longline fishery. Swordfish CPUE has not declined significantly. The CPUE for sailfish and spearfish fluctuated widely but displayed an increasing trend during the 1952-76 period. No reliable estimate of MSY is available for any of the Indian Ocean billfishes. However, the available data suggest that no substantial increase in total yield can be expected for blue marlin and black marlin. The potential for an increased yield for striped marlin appears to be greater. The swordfish and sailfish stocks do not appear to have been affected appreciably by effort exerted to date.

2.4 General Problems in Stock Assessment

2.4.1 Effort

The workshop discussed effort and CPUE in the longline fisheries as they are affected by (1) the use of deep longlines, (2) changes in preferred (target) species or fishing area, (3) reliability of CPUE statistics in the beginning of a fishery, and (4) possible gear competition or interference at high fishing intensities.

2.4.2 Age, growth, and mortality

Workshop participants discussed various aspects of estimating growth and mortality parameters and of estimating age composition of the catch. Aging techniques now being developed for tunas should lead to improvements in knowledge of growth and mortality rates.

2.4.3 Assessment of the effect of fishing

Many assessments discussed at the workshop were based on production model analyses. A number of problems connected with the use of this approach were raised. These problems are discussed in detail in the rapporteurs' reports and in Section 3.11.

Another topic discussed at the workshop was the assessment of interactions between surface fisheries and longline fisheries. It was noted that the interactions are affected by (1) the difference in size of fish taken by the two gears, (2) the natural mortality rate during the period between exposure of fish to the surface fishery and subsequent recruitment to the longline fishery, and (3) the difference in areas exploited by the two fisheries.

Few explicit yield-per-recruit (Y/R) computations were presented for the various stocks. Detailed Y/R analyses would be useful in elucidating the likely responses of the stocks to different patterns of fishing, and in studying the interaction between surface and longline fishing.

Finally, although the very high fecundity of tunas suggests that recruitment is likely to be independent of spawning stock over a wide range of spawning stock size, the matter of stock-recruitment relationships deserves careful attention because of the increased likelihood of reduced recruitment at the high levels of fishing being approached in several fisheries.

2.5 Estimates of Total Catch by Species

Statistics on catches of tunas and billfishes from the Pacific and Indian Oceans were presented in various background papers. Following the conclusion of the workshop additional data were obtained and compiled by the Honolulu Laboratory, including some on Korean tuna and billfish catches. Statistics from these various sources were assembled to provide revised estimates of total catches of tunas and billfishes in the Indian Ocean and of tunas in the Pacific. The revised figures are presented in Tables 1 and 2. The reader should not be concerned over discrepancies between the estimates in these tables and those presented in the individual rapporteurs' reports.

TABLE 1. Estimated catches of tunas in the Pacific Ocean[1]

Year	North Pacific albacore	South Pacific albacore	Bigeye tuna	Northern bluefin tuna	Southern bluefin tuna	Yellowfin tuna
			(Thousand metric tons)			
1949					0.3	
1950					0.1	
1951					<0.1	
1952	93.9	0.2	29.6	13.6	0.8	115.8
1953	76.7	1.1	25.4	21.0	4.2	103.2
1954	61.5	10.2	29.1	24.5	2.8	107.5
1955	54.4	8.4	44.3	28.5	3.4	103.5
1956	76.4	6.2	36.9	33.5	15.8	110.8
1957	92.2	9.8	70.5	29.5	22.9	145.9
1958	55.6	21.7	91.7	22.0	14.4	144.0
1959	51.2	19.8	81.8	14.8	65.9	137.5
1960	63.3	24.4	89.9	19.3	78.7	189.6
1961	52.6	26.0	135.6	19.8	80.9	205.4
1962	47.2	39.5	124.2	25.0	46.0	184.9
1963	68.8	35.5	149.8	24.1	65.4	172.6
1964	62.3	25.0	104.3	19.9	50.5	188.2
1965	72.9	27.4	79.1	18.9	47.7	173.8
1966	65.9	41.4	83.9	28.2	47.7	193.1
1967	82.7	45.4	88.7	15.5	66.2	158.7
1968	69.0	32.4	73.6	15.8	57.9	194.9
1969	75.1	25.4	99.7	13.3	59.4	220.2
1970	67.3	30.7	79.0	8.6	46.8	241.4
1971	92.5	38.6	76.3	17.0	46.6	200.1
1972	105.9	41.9	100.0	19.0	50.9	279.3
1973	107.5	48.8	105.8	15.5	40.2	329.3
1974	114.8	32.3	102.6	16.2	47.1	372.6
1975	86.3	26.8	113.8	16.4	32.2	357.6
1976	123.7	34.4	141.9	15.8	41.2	417.0
1977	61.6	40.2	140.4	13.6	43.5	394.4
1978	96.8				31.8	

[1]Source:

North Pacific albacore. Data for Canada, Japan, Taiwan, and United States from the Report of the Fifth North Pacific Albacore Workshop, La Jolla, California, 30 June-3 July 1980. In N. Bartoo and S. Kume (Ed.), Southwest Fish.Cent.Admin.Rep. (in prep.).

South Pacific albacore. Data for Japan 1952-77, Korea 1958-70, Taiwan 1962-77, and other 1965-77 (from SAWS/BP/8); Korea 1971-77 (from B.Y. Kim, Fisheries Research and Development Agency, Pusan, Korea. Pers. commun., July 1979).

Bigeye tuna. Data for IATTC 1967-77, Japan 1952-77, Korea 1965-70, and Taiwan 1954-77 (from SAWS/BP/6); and Korea 1971-77 (from B.Y. Kim. Pers. commun., July 1979).

Northern bluefin tuna. Data for IATTC 1952-77 (from SAWS/BP/9); Japan 1952-77 (from SAWS/BP/10); and Korea 1971-77 (from B.Y. Kim. Pers. commun., July 1979).

Southern bluefin tuna. Data from G.I. Murphy, Division of Fisheries and Oceanography, CSIRO, Cronulla, N.S.W., Australia. Pers. commun., July 1980. The combined southern bluefin tuna catch is reported here with the Pacific Ocean catches, but includes fish taken in the Indian and Atlantic Oceans also.

Yellowfin tuna. Data for IATTC and Japan 1952-77, Korea 1964-70, and Taiwan 1954-77 (from SAWS/BP/2); Korea 1971-77 (from B.Y. Kim. Pers. commun., July 1979); Australia, Fiji, Kiribati, New Zealand, Papua New Guinea, and Philippines 1967-69 (from FAO, 1974a), 1970-72 (from FAO, 1976), 1973 (from FAO, 1977), and 1974-77 (from FAO, 1978).

TABLE 2. Estimated catches of tunas and billfishes in the Indian Ocean[1]

Year	Albacore	Bigeye tuna	Yellowfin tuna	Blue marlin	Striped marlin	Black marlin	Swordfish	Sailfish and spearfish
				(Thousand metric tons)				
1952	0.1	1.5	8.9	0.8	0.1	0.3	<0.1	<0.1
1953	1.1	3.6	13.3	2.0	0.3	0.8	0.1	0.1
1954	2.8	8.0	25.1	2.3	0.8	1.1	0.2	0.2
1955	3.3	10.3	47.1	3.7	0.8	1.2	0.2	0.2
1956	4.8	14.0	65.5	5.2	1.7	1.7	0.5	0.3
1957	4.7	13.3	37.3	3.9	1.9	1.8	0.4	0.3
1958	6.3	12.8	27.6	4.3	1.9	1.7	0.6	0.5
1959	10.4	10.4	26.8	4.6	2.5	1.7	0.6	0.8
1960	11.1	17.0	42.5	4.0	2.3	2.0	0.7	0.7
1961	15.4	15.5	37.4	3.5	2.7	1.9	0.9	0.6
1962	17.7	19.9	55.1	3.5	2.0	2.1	1.1	1.0
1963	12.6	14.2	29.4	2.6	1.8	1.5	1.1	0.7
1964	18.1	19.0	30.1	3.7	1.9	1.7	1.3	0.8
1965	12.4	20.1	34.5	3.9	3.3	1.3	1.3	1.2
1966	17.3	26.4	56.8	3.8	4.2	1.4	1.4	1.3
1967	23.7	26.9	44.8	4.1	4.5	1.5	1.8	2.0
1968	17.4	38.7	88.1	4.0	3.4	2.5	2.0	1.6
1969	21.9	27.4	61.7	3.9	4.7	2.3	2.3	1.2
1970	15.2	24.8	42.6	3.1	3.1	1.8	2.3	1.0
1971	10.2	22.8	50.9	2.5	2.1	1.4	1.6	1.3
1972	11.7	18.1	47.4	2.5	1.5	0.9	1.6	1.1
1973	22.1	16.0	41.2	1.9	1.1	0.7	1.1	0.4
1974	28.2	27.7	43.5	2.4	2.8	1.3	1.8	0.7
1975	11.2	39.7	51.4	2.3	2.1	1.2	1.3	1.0
1976	14.9	29.8	56.4	1.7	3.4	0.5	1.1	0.6
1977	11.4	36.8	70.5	——— Data incomplete ———				

[1]Source:

Albacore. Data for Japan 1952-77, Korea 1965-70, Taiwan 1963-77, and U.S.S.R. 1965-76 (from SAWS/BP/21); Korea 1971-77 (from B.Y. Kim, Fisheries Research and Development Agency, Pusan, Korea. Pers. commun., July 1979).

Bigeye tuna. Data for Japan 1952-77, Korea 1966-70, Taiwan 1954-77, and Yemen 1974-77 (from SAWS/BP/18); Korea 1971-77 (from B.Y. Kim. Pers. commun., July 1979); Sri Lanka 1963-73 and U.S.S.R. 1963-76 (from SAWS/BP 21).

Yellowfin tuna. Data for Japan 1952-77, Korea 1966-70, and Taiwan 1954-61 (from SAWS/BP/17); Taiwan 1962-77 (from SAWS/BP/21); Korea 1971-77 (from B.Y. Kim. Pers. commun., July 1979); Bangladesh 1965-69, India 1965-70, Maldive Islands 1965-66, Pakistan 1965-70, Sri Lanka 1964-70, and U.S.S.R. 1963-70 (from FAO, 1974b); Australia 1971-72, India 1971-74, Madagascar 1972-74, and Pakistan, Sri Lanka, and U.S.S.R. 1971-73 (from FAO, 1975); Yemen 1974-76 (from FAO, 1977); Comoro Islands, Sri Lanka, and Tanzania 1974-77 (from FAO, 1978); Maldive Islands 1967-77 (from FAO, 1974a, 1976, 1977, 1978); Oman 1973-77 (from FAO, 1977, 1978); Seychelles 1970-77 (from FAO, 1976, 1977, 1978); Yemen 1970-73 (from FAO, 1976, 1977).

Blue marlin. Japan 1952-77, Korea 1965-76, and Taiwan 1963-77 (from SAWS/BP/21); Taiwan 1955-62 (from SAWS/BP/20); Tanzania 1974-77 (from FAO, 1978); U.S.S.R. 1967-69 (from FAO, 1974a), 1970-72 (from FAO, 1976), 1973 (from FAO, 1977), and 1974-77 (from FAO, 1978).

Striped marlin. Japan 1952-77, Korea 1965-76, and Taiwan 1963-77 (from SAWS/BP/21); Taiwan 1957-62 (from SAWS/BP/20).

Black marlin. Japan 1952-77, Korea 1965-76, and Taiwan 1963-77 (from SAWS/BP/21); Taiwan 1955-62 (from SAWS/BP/20).

Swordfish. Japan 1952-77, Korea 1965-76, and Taiwan 1963-77 (from SAWS/BP/21); Taiwan 1957-62 (from SAWS/BP/20); U.S.S.R. 1973-77 (from FAO, 1978).

Sailfish and spearfish. Japan 1952-77, Korea 1965-76, and Taiwan 1963-77 (from SAWS/BP/21); Taiwan 1958-62 (from SAWS/BP/20); U.S.S.R. 1974-77 (from FAO, 1978).

3. RAPPORTEURS' REPORTS

3.1 Statistics and Other Data[3] (Rapporteurs: John A. Gulland and Robert A. Skillman)

3.1.1 General remarks

A reliable and comprehensive data base, including information on total catches, fishing effort and corresponding catch, size composition, age and growth, and mortality rates is essential for stock assessment and other related studies. While comprehensive data are available for parts of the region being considered, the coverage is not complete, particularly in some areas of the western Pacific and the Indian Ocean.

The workshop therefore paid attention to reviewing the existence and quality of the data available. In general, the quality of the data available was considered to be good. The implications of the strengths and weaknesses revealed in the data to the study and assessment of the individual stocks are discussed in the relevant parts of this report dealing with each species.

3.1.2 Problems of different types of fisheries

3.1.2.1 Small-scale or artisanal fisheries

Catches in these fisheries, taken by a variety of gears, are individually small but in countries with a large number of scattered fishermen, the total catch can be substantial, e.g., in Indonesia and Philippines. Comprehensive data from these fisheries are often not available. Total catch figures are often very imprecise, with little details of species composition. Much of the catch, if not all, is consumed locally, so there is little opportunity of checking the accuracy of catch statistics using other records, e.g., exports, or production of canned tuna. Improvements in these statistics will have to come as part of a general improvement in collection and processing of national fishery statistics. Assistance from tuna research organizations, whether national or regional, will be particularly useful in identifying the species caught.

3.1.2.2 Local or medium-range industrial-scale fisheries

Some of the necessary data on catches, species composition, and fishing effort normally exist in the commercial records for these fisheries. The main need is to expand national data collection systems to include information now not gathered and to improve data compilation. There may be problems in interpreting fishing effort data but these are due to shortcomings in analysis rather than data collection as such. Another problem is the failure to distinguish between species in the catch records, especially in small tuna, e.g., the Japanese "meji" catches, or possibly, small yellowfin tuna in surface fisheries for skipjack tuna. Biological sampling may therefore be necessary to supplement the commercial records.

3.1.2.3 Long-range fisheries with vessels landing in home ports

The major problem here is to determine where the fish have been caught and, for long voyages, when they were caught. Properly kept standardized logbooks, supplemented by interviews at the time of landing should deal with this problem.

3.1.2.4 Transshipments

Several countries can be concerned with transshipment catches: the flag country of the vessel, the home country of the company controlling the vessel, the home country of its crew (which is not always the flag country), the country in whose waters the fish is caught, the country in which the fish is first landed or transshipped, and the country of

---

[3]Note: The workshop did not include skipjack tuna in its deliberations.

ultimate destination. Each of these countries may or may not include these catches in its national statistics, so that the catches may be reported several times, or not at all. This can seriously complicate attempts to compile statistics of total catch or landings by all countries. One way to avoid double reporting is to have catches reported to the appropriate agency by the flag state only. But unless all flag states do this, this procedure could lead to underreporting of the catches. An alternative is to designate a central agency responsible for information on the fisheries of a region, such agency to be supplied with full details of individual catches and landings in the region, and to be responsible for sorting through these data to eliminate duplications and detect possible omissions.

Transshipment statistics often lack information on date and place of capture. Again, logbooks are highly desirable. Further, since several countries--the flag state, the control state, and one or more transshipment states--are concerned with the records of the same vessel, it is highly desirable that the format of the logbook should be standardized on at least a regional basis.

Any regional institution should, as far as possible, cover the whole range of the major stocks of interest, and receive data from all countries fishing these stocks. Indeed, in taking account of the movements of many tuna vessels between regions, a common global standard (or at least compatible regional standards) would be desirable. The workshop also considered to what extent the vast region covered by the different stocks discussed during the meeting could be divided into smaller regions, each served by a separate institution.

Interchange of fish between the Pacific and Indian Oceans is unclear but is believed to be small. An exception is the southern bluefin tuna with its nearly complete circumpolar distribution. The data problem for this species is relatively slight since only two countries have significant fisheries and each has a good data base including a regular bilateral exchange system. The catches and related fisheries data for the Indian Ocean could be handled separately from those in the Pacific, though there could be savings in operational costs if they were handled jointly.

Within the Pacific there is considerable movement by many of the tuna species. It is not possible to suggest any dividing line that could be used to separate areas of interest of different institutions that would not cut across the area of distribution of one or more major stocks. From one point of view a single institution for the whole Pacific, at least outside the area of the IATTC, would be most appropriate. The workshop noted that the island countries of the western Pacific are using a standard logbook format developed by the South Pacific Commission. It is believed that such logbooks should be more generally adopted.

3.1.2.5 Joint ventures

The risks of double reporting, or of neither country reporting again exists, but with joint ventures they are easier to overcome. With greater control being exercised by the coastal state it is possible that in the future statistics of joint venture operations will be collected and compiled by the coastal state, and reported by it to the appropriate regional or global authority. However, the need remains for careful checking by such authorities to insure that statistics of joint venture operations are being properly reported without omission or duplication.

3.1.2.6 Sport fisheries

Sport fishermen can have considerable importance in some areas and make significant catches of some stocks. The technical problems of collecting data (e.g., from sampling surveys) are very similar to those of small-scale fisheries.

3.1.3 Changes in the Law of the Sea

Changes in maritime law, and especially the extension of jurisdiction over fisheries by coastal states, have led to increased interest in fisheries and fisheries statistics.

Ultimately this should lead to better data. The application of additional controls has resulted in a drop in the quality of the information available from many fisheries, with possible deliberate misreporting of position of capture, quantity taken, etc. There is no easy answer to this problem. Collection of reliable data depends on the cooperation of the fishermen, and systems of control should as far as possible maintain the goodwill of the fishermen, and minimize the incentive for misreporting.

3.1.4 Priorities

The first priority should be collection of statistics on total catch. Data on fishing effort and resulting catch and detailed position of capture are also required but may receive lower priority. There are advantages, in terms of improving data on total catch, in establishing a single system for all data.

3.1.5 Action needed

3.1.5.1 National

There are a number of countries landing (or believed to land) substantial quantities of tuna for which the statistical information is inadequate. The workshop recommended strongly that these countries should take action to improve these data. The specific actions needed will depend on national conditions, and these were not discussed in detail, but are likely to include some or all of the following:

(i) general improvement in the national statistical systems,

(ii) better identification of small tunas, and

(iii) use of logbooks by the commercial vessels.

3.1.5.2 Regional

Adequate statistics for all tunas in the western Pacific and Indian Ocean will not be readily available in a convenient form, until there is a regional institution (or institutions) responsible for the compilation of data from national resources, and for the regular checking of the quality and completeness of the data. The activities of such a body could be patterned after existing bodies such as ICCAT or IATTC.

3.1.5.3 Interregional

Whatever regional institutions are set up, there is bound to be some interchange of fish between their areas of responsibility, e.g., migration of northern bluefin tuna between the eastern and western Pacific, or of southern bluefin tuna between the Pacific, Indian, and Atlantic Oceans. Also many tuna vessels move freely between oceans. Therefore there is a strong need for collaboration between the institutions handling regional data in all parts of the world.

Regional agencies will have to play an important role in encouraging the adoption of standard logbooks for the stocks fished by all countries. They could also assist by encouraging a full exchange of data among countries for stock assessment purposes. For example, the availability of data from major longline fishing nations would be particularly beneficial in the Indian Ocean where indices of yellowfin tuna abundance have previously been based on Japanese statistics. Since the Japanese share of the Indian Ocean yellowfin tuna catch has declined dramatically in recent years, it is increasingly important that statistics on the yellowfin tuna catch by other countries fishing in the region be improved and made available. An interregional body could help a full exchange of the important fisheries statistics.

3.2 Pacific Yellowfin Tuna (Rapporteurs: Norman W. Bartoo and Ziro Suzuki)

Yellowfin tuna, Thunnus albacares, are distributed throughout the Pacific Ocean between approximately lat. 45°N and 45°S but are most abundant between lat. 20°N and 20°S. Surface gear (purse seine, pole and line, troll) and subsurface gear (longlines and handlines) are used throughout the Pacific to catch yellowfin tuna. In the eastern Pacific the purse seine fishery dominates the yellowfin tuna landings (Figure 1), whereas in the western Pacific the longline fishery is of greatest importance (Figure 2).

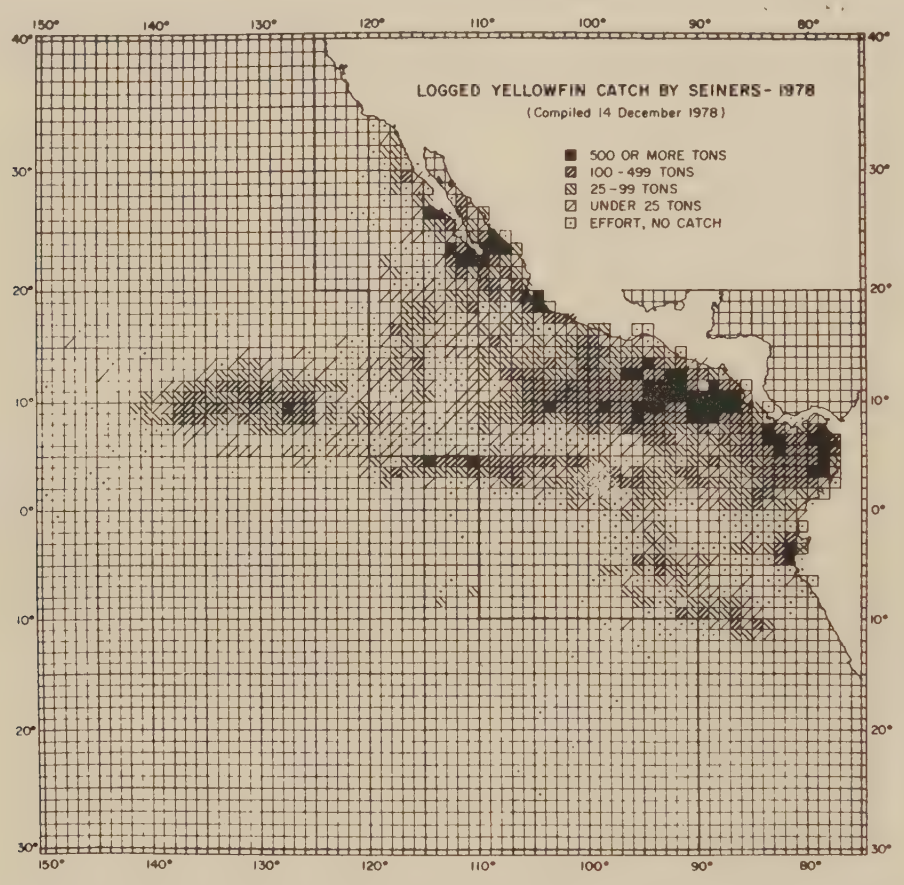


Figure 1. The yellowfin tuna purse seine fishery in the eastern Pacific Ocean in 1978 (from IATTC, 1979)

3.2.1 Review of current research

The discussion on Pacific yellowfin tuna research results included a detailed review of the available estimates of life history and population dynamics parameters (SAWS/BP/1). The necessity for further studies on growth, particularly for western Pacific yellowfin tuna, was noted.

Two background papers (SAWS/BP/2 and SAWS/BP/4) concluded that surface and longline gears apparently interact most when fishing in the same areas. The stock structure of Pacific yellowfin tuna was discussed and in the light of two background papers (SAWS/BP/2 and SAWS/BP/3) it was concluded that separate east and west stocks most likely exist, perhaps separated by a less well-defined central stock.

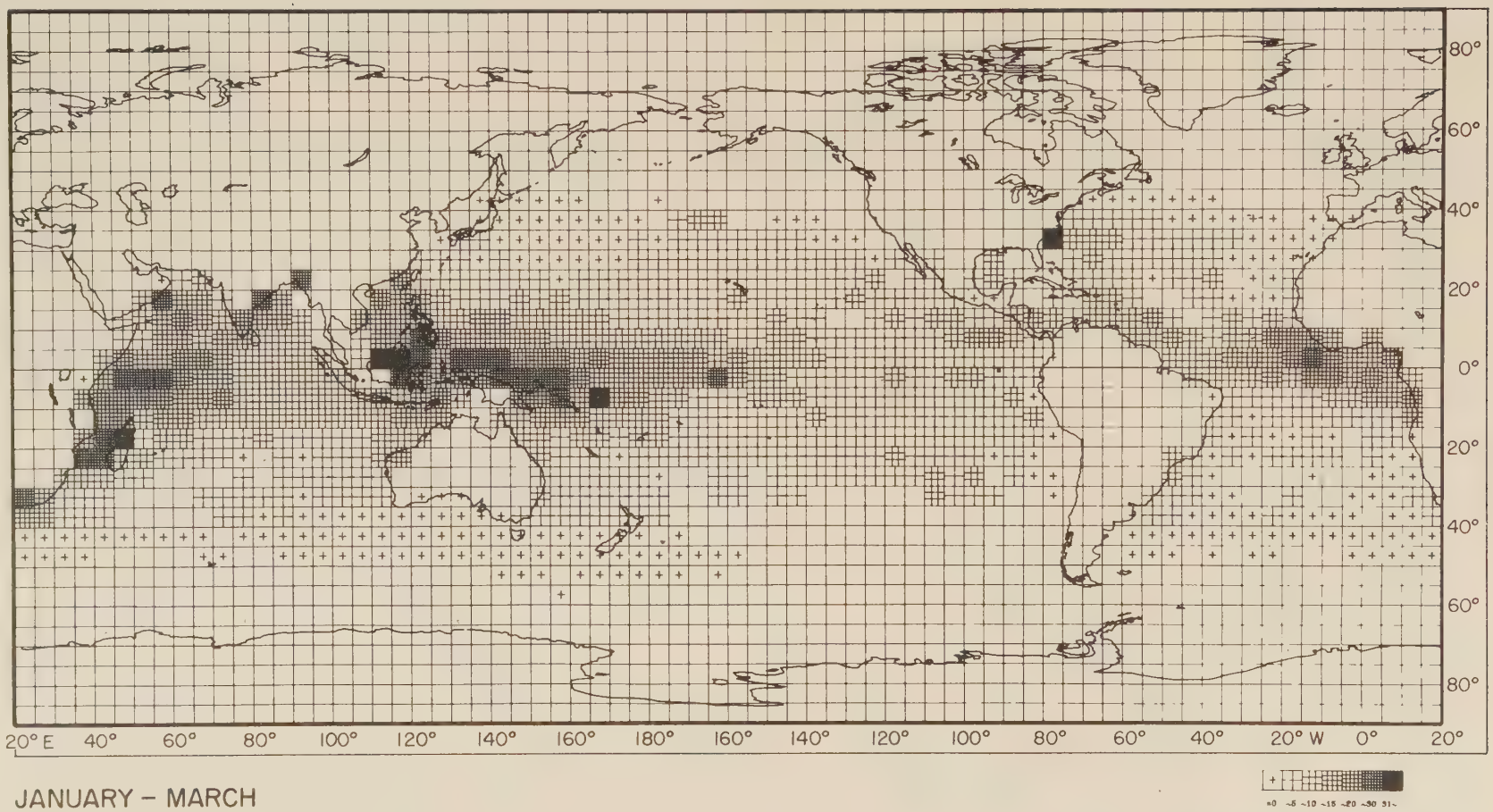


Figure 2. Average quarterly distribution of yellowfin tuna longline catch rates in the Pacific Ocean, 1966-75 (from SAWS/BP/2)

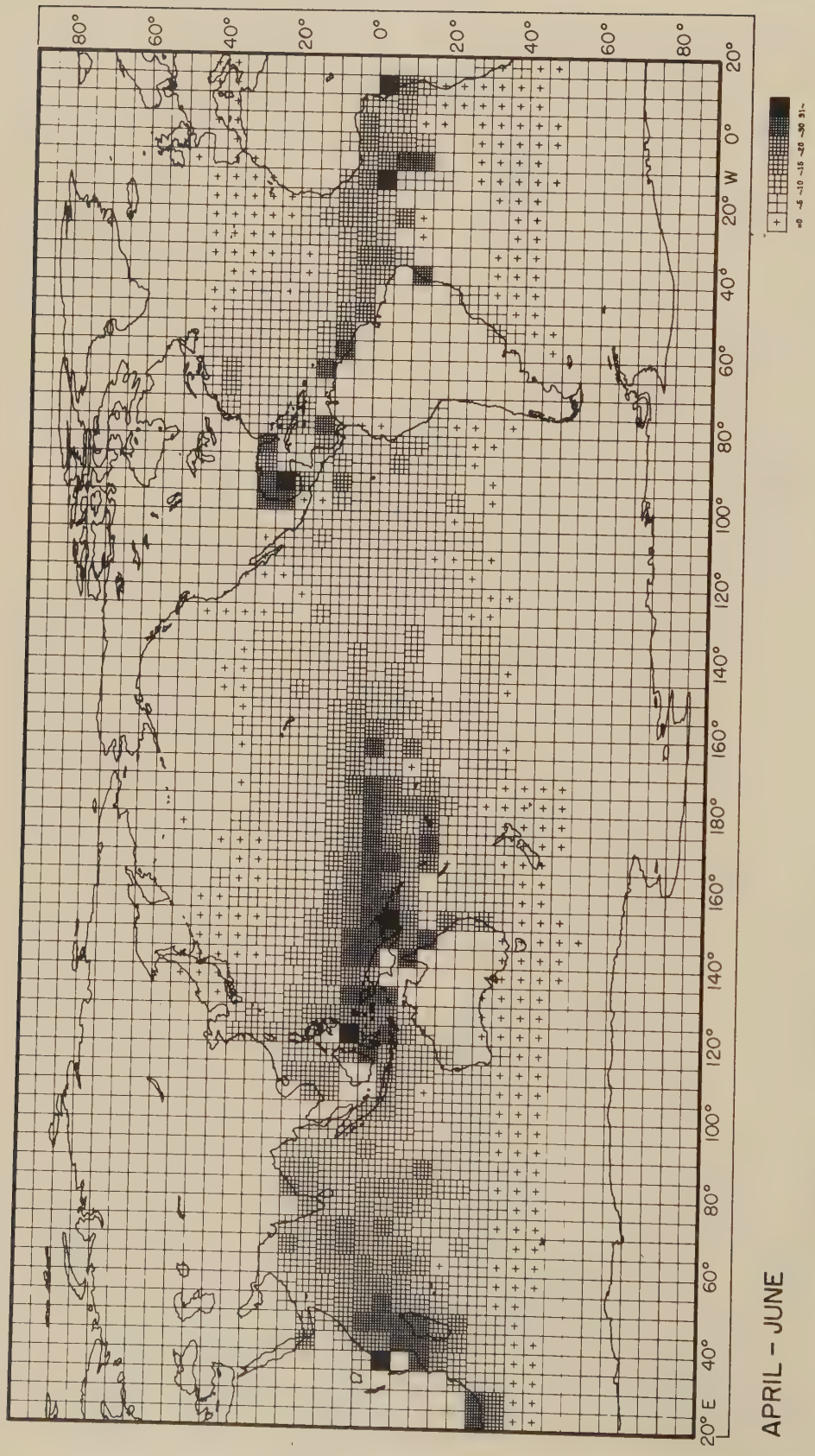


Figure 2. Continued

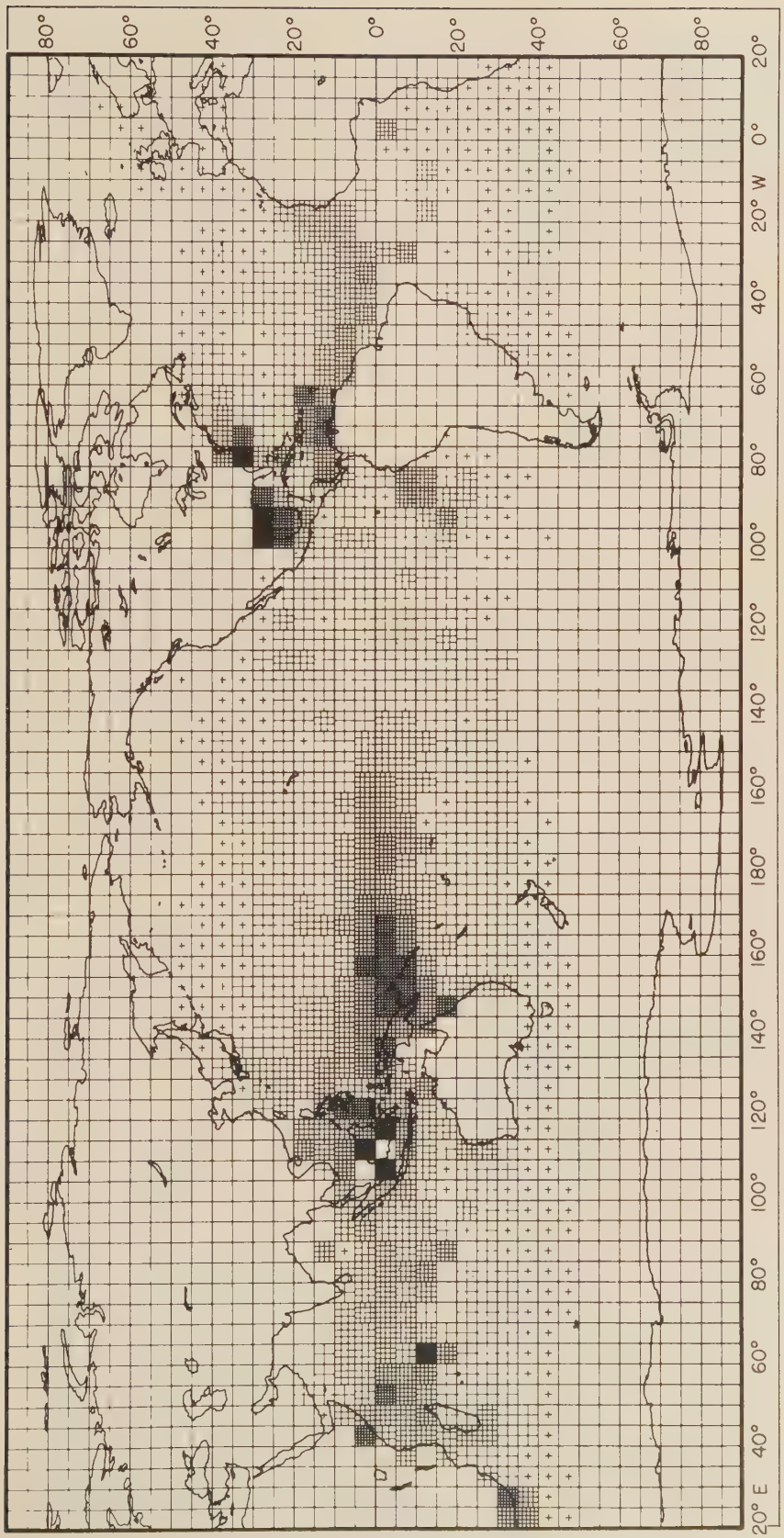
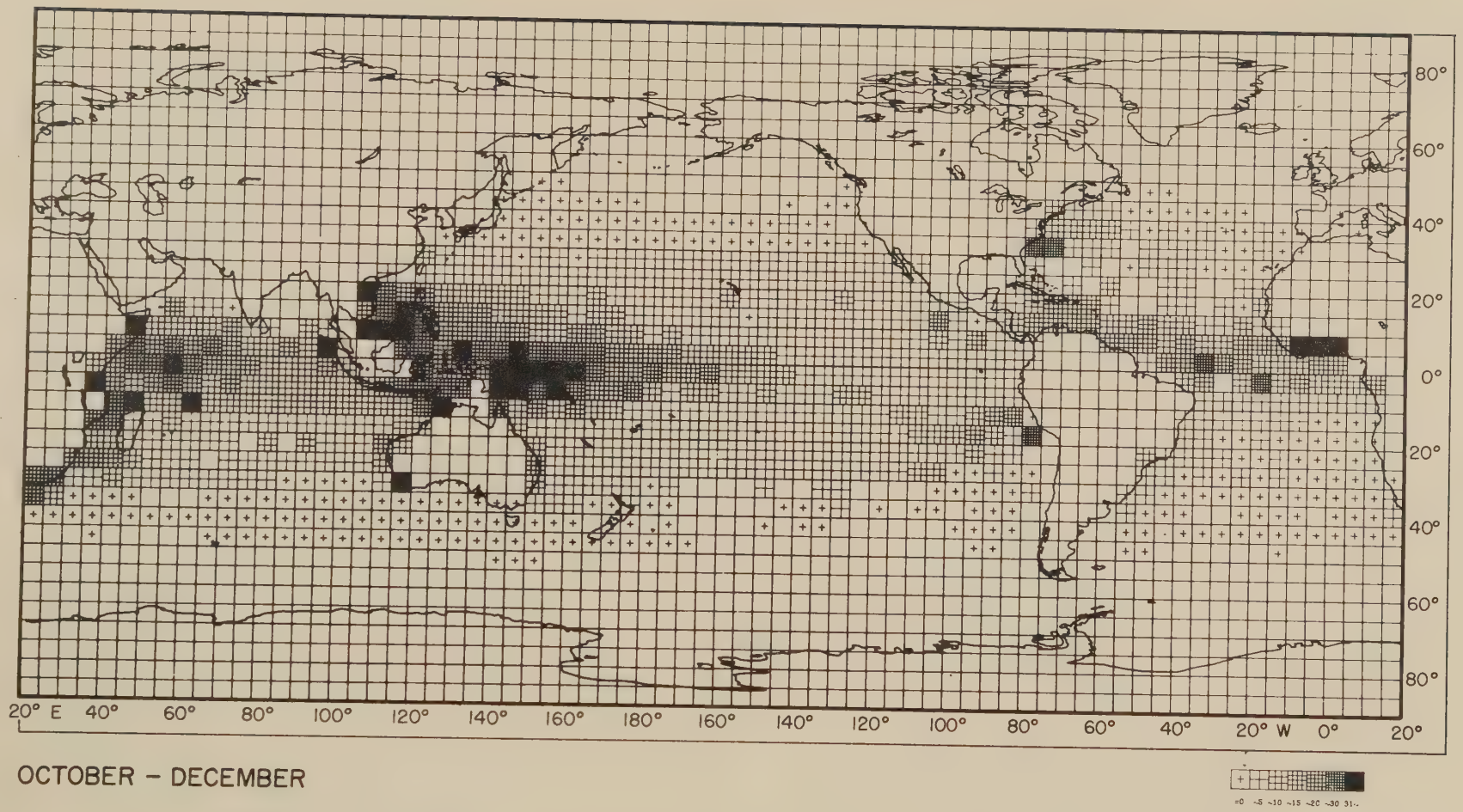


Figure 2. Continued



OCTOBER - DECEMBER

Figure 2. Continued

3.2.2 Review of fishery data

A great deal of attention was devoted to evaluating the quality and coverage of yellowfin tuna fishery data in the Pacific. The participants felt that the data from the ETP were adequate, whereas data from the central and western Pacific were in some cases not as good. Catch and effort data for some longlining countries were unavailable. Biological data (size frequency) for longline fisheries were available only from Japanese fishery.

The western Pacific statistics were considered poor for total catch estimates because several countries were not reporting catches or were aggregating yellowfin tuna catches with other species. Particular attention was given to the lack of surface catch data from the Philippines and for United States purse seiners fishing in the western Pacific. The yellowfin tuna catch of the Philippines was thought to be especially large. Because of possible impacts on stock assessments, high priority should be placed on collecting catch statistics from the Philippines, including historical data. No statistics were available for some of the smaller South Pacific island countries but catches were known to be small in these areas.

The problem of double reporting of some transshipped catches was also noted, although no specific data were singled out.

3.2.2.1 Catch trends

Yellowfin tuna catch data which were available to the meeting are summarized in Table 3. Total Pacific catches show a slow increase from 1952 to 1961, level off in the 175,000-195,000 MT range from 1962 through 1968, and rise rapidly to about 400,000 MT from 1969 through 1977 (Figure 3). About half of the Pacific yellowfin tuna production is from the ETP, in the IATTC regulatory and nonregulatory areas, and catches from this area and from the Philippines (since 1974) account for most of the total recorded catch increase in recent years.

Figure 3.--Estimated annual Pacific-wide catch of yellowfin tuna, 1952-77 (data from SAWS/BP/2)

TABLE 3. Estimated catch (metric tons) of yellowfin tuna in the Pacific Ocean, 1952-77 (from SAWS/BP/72)

Year	Japan							Korea	Taiwan			Philippines	Others	Eastern Pacific fishery	Grand total
	Long-line[1]	Long-line[2]	Bait boat	Purse seine	Others	Young	Total	Long-line	Long-line	Others	Total				
1952	22,477	322	2,595	--	3,192	--	28,586	--	--	--	--	--	--	87,182	115,768
1953	33,288	--	5,228	192	1,456	--	40,164	--	--	--	--	--	--	63,005	103,169
1954	34,174	255	4,268	3,900	853	--	43,450	--	1,192	--	1,192	--	--	62,869	107,511
1955	[3]28,794	154	3,983	2,580	1,392	--	36,903	--	2,724	--	2,724	--	--	63,912	103,539
1956	[3]22,717	--	4,399	709	293	--	28,118	--	2,377	--	2,377	--	--	80,287	110,782
1957	60,976	353	1,669	1,095	916	4,856	69,865	--	2,109	--	2,109	--	--	73,937	145,911
1958	60,608	177	2,934	2,983	1,332	6,895	74,929	--	1,753	--	1,753	--	--	67,335	144,017
1959	55,146	327	4,119	4,032	1,462	7,103	72,189	--	1,568	--	1,568	--	--	63,722	137,479
1960	68,438	254	1,872	1,436	571	4,914	77,485	--	1,301	--	1,301	--	--	110,827	189,613
1961	84,527	295	3,259	2,766	820	6,696	98,363	--	2,606	--	2,606	--	--	104,432	205,401
1962	79,632	291	4,225	6,705	1,223	8,350	100,426	--	5,513	--	5,513	--	--	78,971	184,910
1963	88,050	267	2,071	2,178	552	8,362	101,480	--	5,149	—	5,149	--	--	65,928	172,557
1964	71,508	150	4,932	3,647	864	8,339	89,440	500	5,795	—	5,795	—	300	92,479	188,514
1965	66,809	195	3,261	3,752	466	7,782	82,265	2,000	7,890	--	7,890	--	100	81,685	173,940
1966	77,469	1,388	2,121	5,843	1,663	7,653	96,137	3,000	10,750	471	11,221	--	100	82,696	193,154
1967	47,982	2,187	3,073	3,395	3,212	9,018	68,867	1,900	5,981	648	6,629	--	100	81,329	158,825
1968	52,265	1,067	2,689	6,886	1,555	8,654	73,116	5,300	10,917	535	11,452	--	100	105,070	195,038
1969	56,110	2,686	2,581	4,329	681	7,133	73,520	3,500	10,178	420	10,598	—	100	132,554	220,272
1970	50,940	4,356	1,932	5,720	1,453	7,244	71,645	2,000	10,096	406	10,502	—	100	157,220	241,467
1971	40,930	3,126	2,382	2,713	435	6,731	56,317	5,300	14,040	364	14,404	--	100	123,961	200,082
1972	53,345	3,803	4,029	4,585	1,097	8,194	75,053	11,800	13,037	331	13,368	--	100	178,989	279,310
1973	47,973	2,585	8,366	7,455	664	10,425	77,468	12,000	18,785	441	19,226	14,900	1,600	206,233	331,447
1974	44,316	2,505	7,132	12,222	948	14,236	81,359	15,104	12,372	334	12,706	51,732	1,511	210,780	373,192
1975	45,996	5,260	3,249	7,790	986	9,393	72,674	10,366	16,441	426	16,867	52,793	1,823	203,124	357,647
1976	55,497	7,146	8,856	10,655	1,624	11,040	94,818	15,613	15,857	1,378	17,235	44,478	8,852	235,980	416,976
1977	57,300	7,626	6,295	10,223	647	11,547	93,638	16,580	19,418	624	20,042	59,263	3,995	200,870	394,388

[1]Vessels over 20 gross tons.

[2]Vessels under 20 gross tons.

[3]Provisional estimate.

The size composition of the yellowfin tuna catches from the ETP is well documented by the IATTC and suggests a greater variability in the age structure of the fish in the catch since 1972 and a greater dependence, on the average, on age 1 fish (Figure 4).

The size composition of yellowfin tuna in the longline catches from the western and central Pacific generally shows a mode near 120 cm fork length (FL) in the main fishing areas (Figure 5).

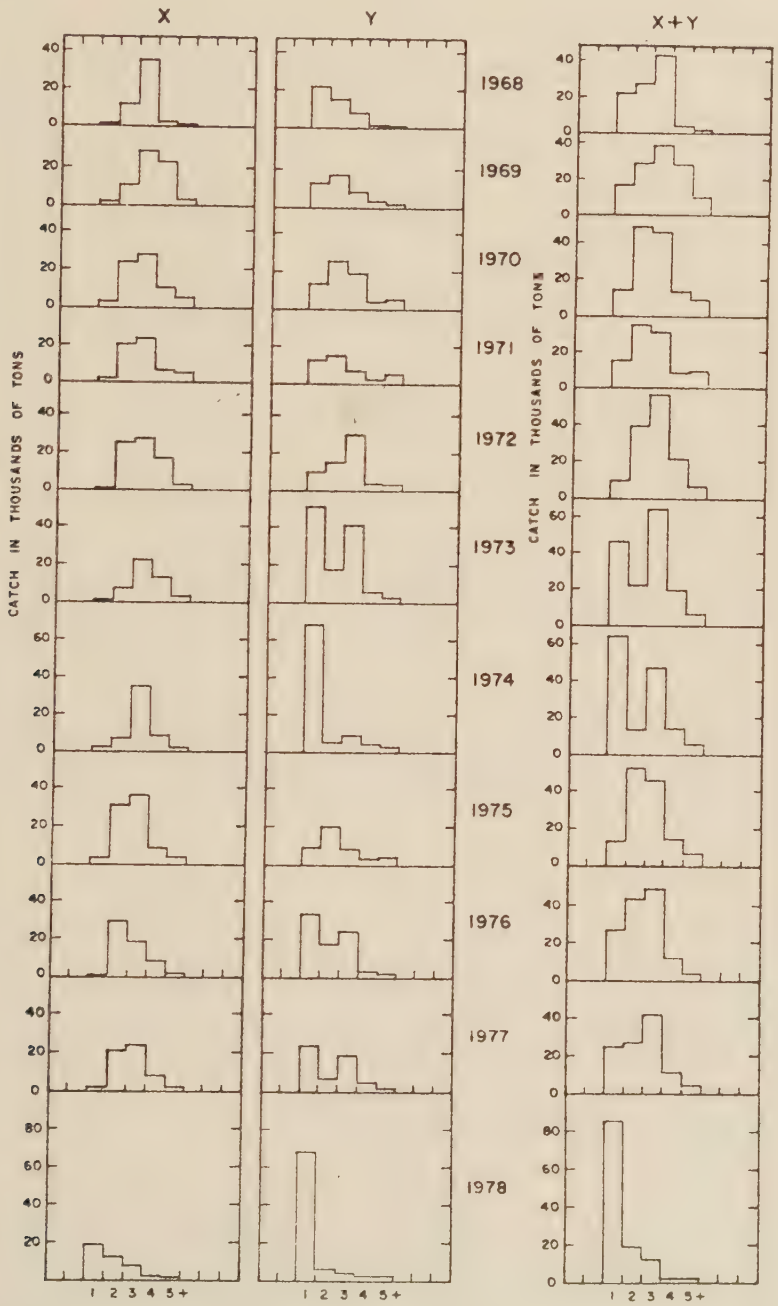


Figure 4. Estimated weights of eastern Pacific yellowfin tuna of ages 1 through 5+ in the first and second quarter purse seine catches, 1968-78, by X and Y groups. The X group enters the fishery during the first half of the year but does not contribute significantly to the fishery until the second half of the year; the Y group enters in the second half of the year but does not contribute significantly to the fishery until the first half of the following year (from SAWS/BP/5)

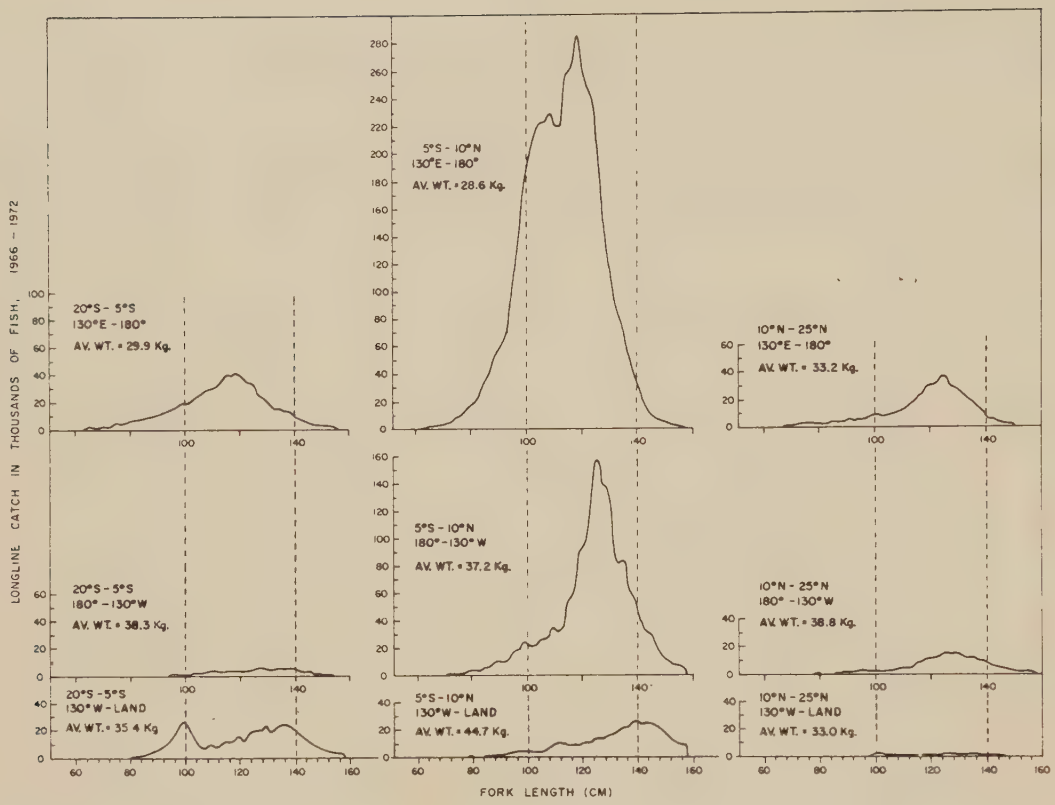


Figure 5. Length frequencies of longline-caught yellowfin tuna for 1966-72 combined, for nine major areas of the Pacific (from SAWS/BP/3)

The group noted that the lack of data from the purse seine fisheries in the central and western Pacific was alarming particularly in light of the report that some of the catches in the Philippines area had a modal size of approximately 40 cm and contained fish as small as 15 cm (SAWS/BP/26).

3.2.2.2 Effort trends

Total longline fishing effort for yellowfin tuna showed a generally increasing trend, from 75 million hooks in 1952 to 548 million hooks in 1977 (Table 4). Japan was responsible for most of the longline fishing effort in early years while in recent years Korea and Taiwan expanded their longline fisheries. The effort statistics available for the surface fisheries are more complete for the eastern Pacific than for the central and western Pacific.

3.2.2.3 Trends in catch per unit effort

For consideration of changes in the longline CPUE the Pacific Ocean was divided into nine areas (Figure 6). After 1962 the effort covered the areas under consideration more comprehensively and data since this time on were more suitable for between-area comparisons of CPUE. In most areas the longline CPUE fell sharply after the first few years of fishing and then showed a relatively steady and gradual decline as effort increased (Figure 7). There was a suggestion that the longline catch rate fell in the eastern central Pacific (area 3 of Figure 6) coincidentally with the extension of the surface fishery into this region. There was a substantial overlap in the area of fishing and in the size of fish caught for the first time in the early 1970's, but it is not known to what extent the decline in longline CPUE could be attributed to the surface fishery.

Table 4. Catch (metric tons) and effective effort ($\times 10^3$ hooks) for yellowfin tuna in the Pacific Ocean, 1952-77 (from SAWS/BP/2)

	Japanese longline fisheries		Total longline fisheries		All gears	
Year	Catch	Effort	Catch	Effort	Catch	Effort
1952	22,477	74,252	22,799	75,316	28,586	94,433
1953	33,288	85,475	33,288	85,475	40,164	103,131
1954	34,174	81,382	35,621	84,828	44,642	106,311
1955	[2]28,794	[2]133,412	[2]31,672	[2]146,747	[2]39,627	[2]183,605
1956	[2]22,717	[2]113,524	[2]25,094	[2]125,403	[2]30,495	[2]152,394
1957	60,976	163,402	63,438	170,000	71,974	192,875
1958	60,608	167,694	62,538	173,034	76,682	212,169
1959	55,146	164,967	57,041	169,602	73,757	219,304
1960	68,438	190,837	69,993	195,173	78,786	219,692
1961	84,527	269,104	87,428	278,339	100,969	321,449
1962	79,632	322,379	85,436	345,876	105,939	428,880
1963	88,050	333,814	93,466	354,347	106,627	404,251
1964	71,508	276,504	77,953	301,425	96,035	371,344
1965	66,809	281,309	76,894	323,773	92,255	388,453
1966	77,469	313,521	92,607	374,785	110,458	447,029
1967	47,982	232,519	58,050	281,308	77,496	375,543
1968	52,265	239,155	69,549	318,243	89,968	411,677
1969	56,110	238,602	72,474	308,188	87,718	373,012
1970	50,940	197,668	67,392	261,508	84,242	326,912
1971	40,930	222,433	63,396	344,525	76,121	413,679
1972	53,345	266,719	81,985	409,916	100,321	501,594
1973	47,973	274,479	81,343	465,402	125,214	716,409
1974	44,316	287,845	74,297	482,580	162,412	1,054,913
1975	45,996	260,001	78,063	441,265	154,523	873,470
1976	55,497	306,615	94,113	519,965	180,996	999,985
1977	57,300	311,091	100,924	547,932	193,518	1,050,640

[1]Excluding the eastern Pacific surface fisheries (CYRA and outside).

[2]Provisional estimate.

It was not possible to detect any impact of the increase in surface fisheries for yellowfin tuna in the western Pacific on the longline catch rates. It was noted that predominately small fish were taken by surface gear in the western regions and it could be more difficult to detect any interaction with the longline fishery. However, the impact of the surface fisheries on the longline catch rates could be expected to be less than that in the eastern Pacific because the ratio of surface to longline catches is smaller in the western Pacific.

3.2.3 Stock structure

The Pacific yellowfin tuna resource was assumed to have separate east and west stocks, and possibly a third stock in the central Pacific. This assumption was based on the distribution of longline catch rates, distribution of fish contaminated by radioactivity during the U.S. Pacific atomic bomb tests, larval fish distribution, and other biological data (SAWS/BP/3). Studies of blood biochemical genetics have indicated heterogeneity in gene frequencies in the eastern Pacific stock.

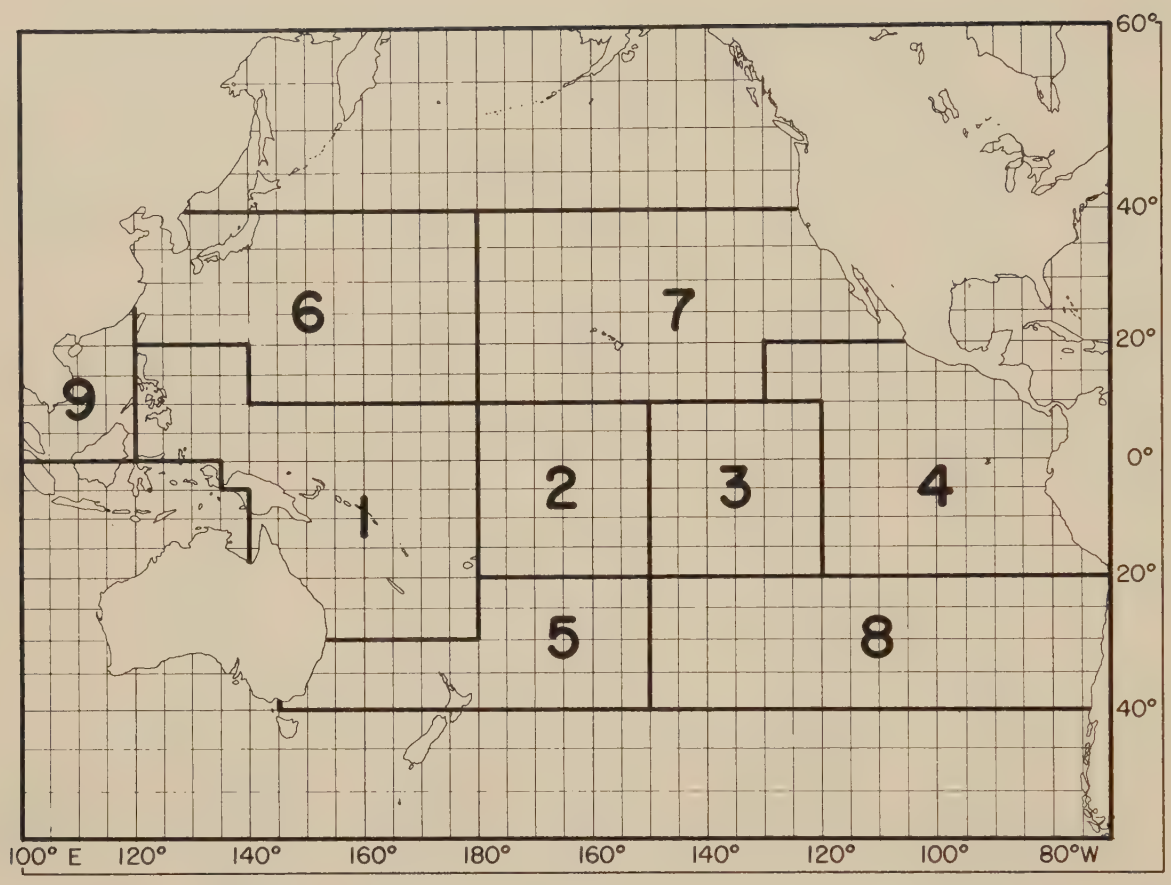


Figure 6. Subareas in the longline fishery for yellowfin tuna in the Pacific (from SAWS/BP/2)

3.2.4 Population parameters

Numerous available population parameter estimates (SAWS/BP/1) were reviewed but no judgments were made on their relative merits.

3.2.5 Status of stocks

3.2.5.1 Production model analysis

A production model analysis for yellowfin tuna in the eastern Pacific CYRA (Figure 8) shows that the current effort is probably above the level producing the MSY, which was estimated at 158,759 MT (175,000 short tons). In recent years there has been an increase in effort and in 1978 a shift towards younger fish in the eastern Pacific purse seine catch.

Production model analyses were not possible for the surface and longline fisheries in the western and central Pacific. An analysis of the entire Pacific longline fishery (Figure 9), which is possibly indicative of the situation in the longline fishery in the western and central Pacific suggests that the total effort is at or approaching the level producing the MSY which had been estimated at around 80,000 to 90,000 MT (SAWS/BP/2). An increase in the longline effort is unlikely to result in a significant increase in sustained catch if the current pattern of fishing is maintained.

No effect of the increased surface fishing activity in the western Pacific could be detected in either the longline or surface fishery CPUE. The surface catches are smaller in the western Pacific, and by analogy with the eastern Pacific and the eastern Atlantic,

it is suspected that there is a potential for increased surface catches, particularly if the effort is exerted on medium and large fish.

3.2.5.2 Yield-per-recruit analysis

A previous Y/R analysis for the ETP (Figure 10) indicated that the fishery was realizing a Y/R of 1.94 kg (4.28 lb) (SAWS/BP/5). With the parameters used, the critical size for yellowfin tuna in the ETP (with the instantaneous natural mortality rate M = 0.8) is near 110 cm (SAWS/BP/5). Given the nature of the ETP fishery, it may not be practical to reduce the instantaneous fishing mortality rate, F, on the youngest fish; however, if this could be done while increasing F on older fish, an increase in Y/R would probably be realized. Estimates of critical size were not available for other natural mortality rates.

No estimate of Y/R is available for the central-western Pacific stock(s) and the group strongly recommended a Y/R analysis be done for this stock(s) for a range of M values. It was noted that the surface fishery in the Philippines may be making substantial catches of yellowfin tuna as small as 15 cm which is not good from a Y/R standpoint especially if the natural mortality rate on the smallest fish is low. Because of the rapidly developing surface fishery in the western Pacific, the Y/R analysis should be done soon.

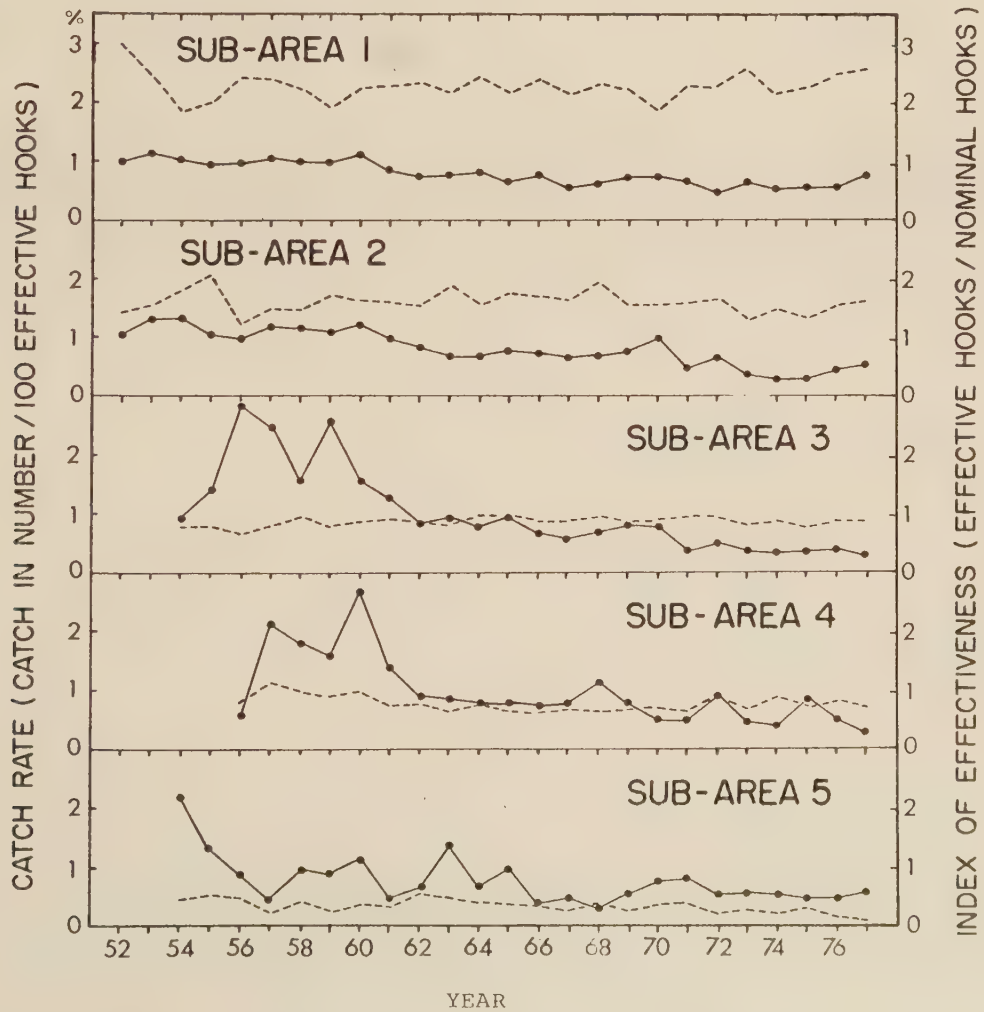


Figure 7.--Catch rate and index of effectiveness for yellowfin tuna in the Japanese longline fishery by subareas. Solid line denotes the catch rate and broken line denotes index of effectiveness (from SAWS/BP/2)

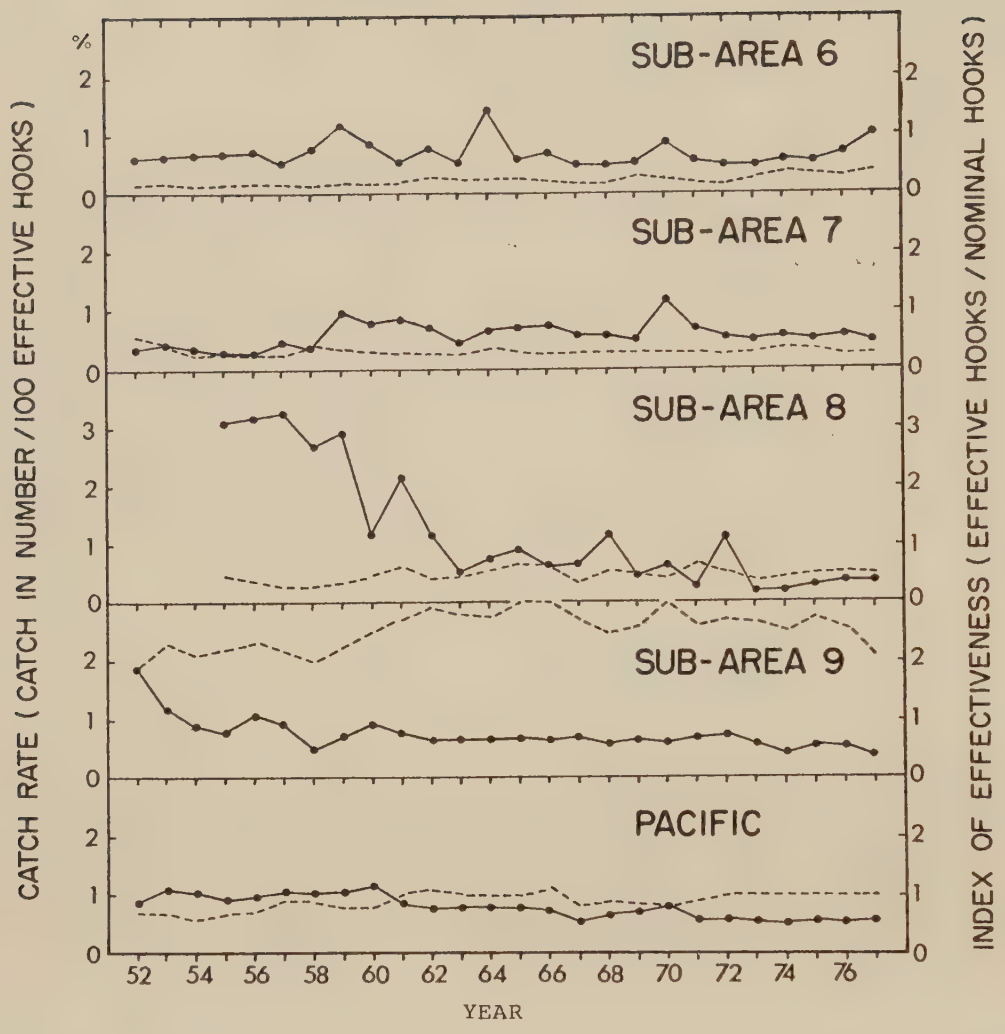

SUB-AREA 6
SUB-AREA 7
SUB-AREA 8
SUB-AREA 9
PACIFIC
%
CATCH RATE (CATCH IN NUMBER / 100 EFFECTIVE HOOKS)
INDEX OF EFFECTIVENESS (EFFECTIVE HOOKS / NOMINAL HOOKS)
YEAR
52 54 56 58 60 62 64 66 68 70 72 74 76

Figure 7. Continued

3.2.5.3 Recruitment analysis

No analysis of the relationship between stock size and subsequent recruitment was presented for any of the Pacific yellowfin tuna stocks. The group did note that the IATTC is investigating the relationship between stock size and recruitment for the yellowfin tuna stock in the ETP.

3.2.5.4 Current appraisal

If effort is maintained at the 1976-78 levels for the next several years in the ETP yellowfin tuna fishery, the catch is most likely to either decrease or remain approximately constant. If the former occurs, it would indicate that the yellowfin tuna stock in the CYRA responds to either a decrease in size of fish taken or to excess fishing effort, or both. If the latter occurs, it could indicate that either the estimates of the parameters used in the production model presented (Figure 8) are faulty or that the yellowfin tuna stock in the CYRA does not respond to fishing according to this type of general production model.

The condition of the central-western yellowfin tuna stock(s) is less clear. It appears that the stock(s) is capable of sustaining the current level of fishing, or perhaps even more as previously discussed, but the absence of much critical data makes such predictions speculative.

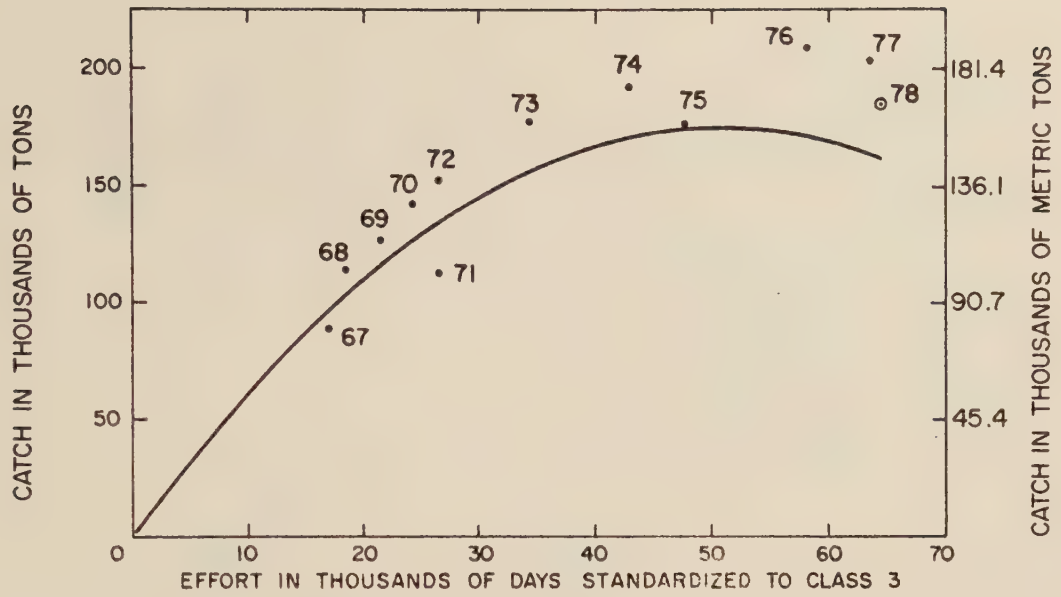


Figure 8. Relationship between effort and catch for the yellowfin tuna fishery within the CYRA, 1967-78 (from SAWS/BP/5) and a logistic model representing this fishery

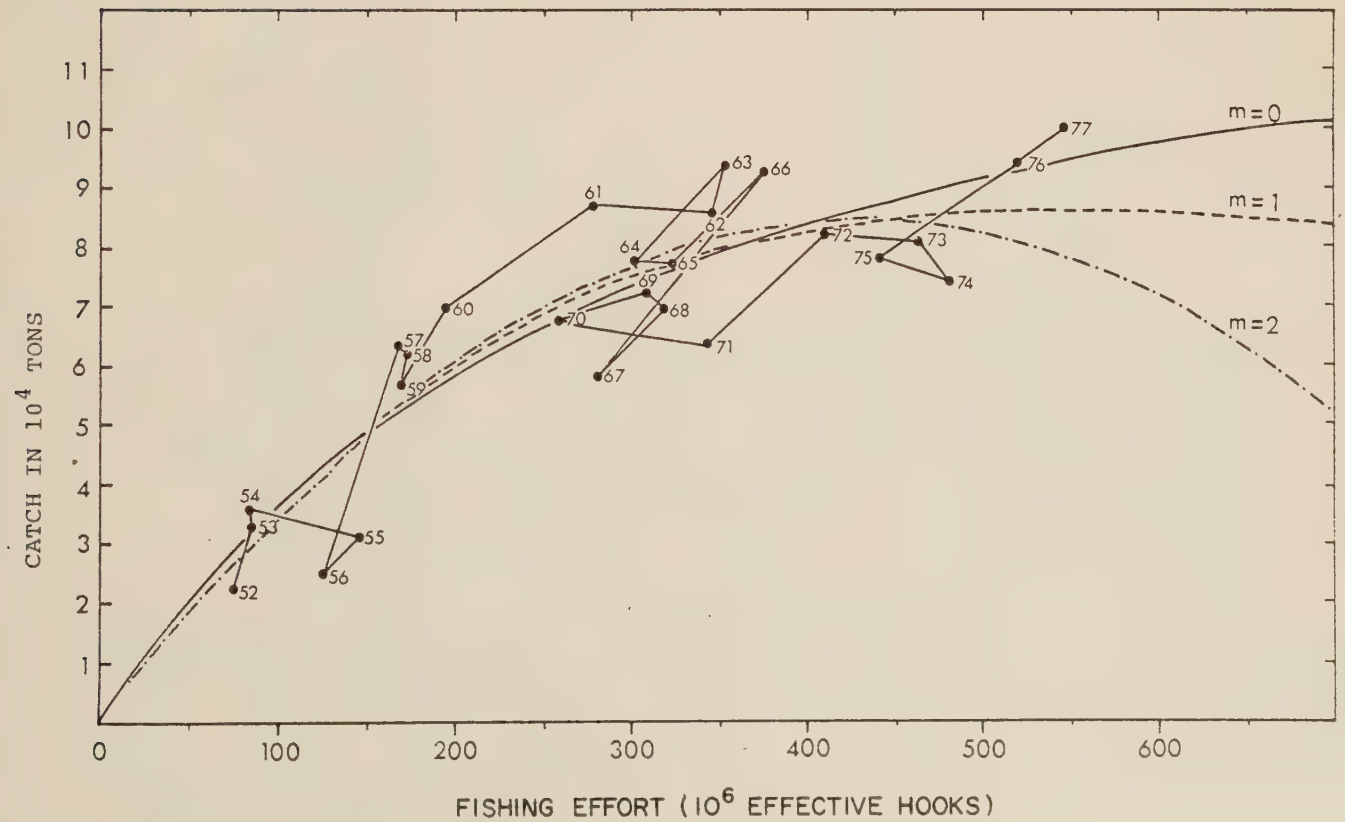


Figure 9. Catch and effort plots with curves fitted to the model for m = 0, 1, and 2 (k = 3), respectively, for yellowfin tuna caught in the Pacific-wide longline fishery, 1952-77 (from SAWS/BP/2)

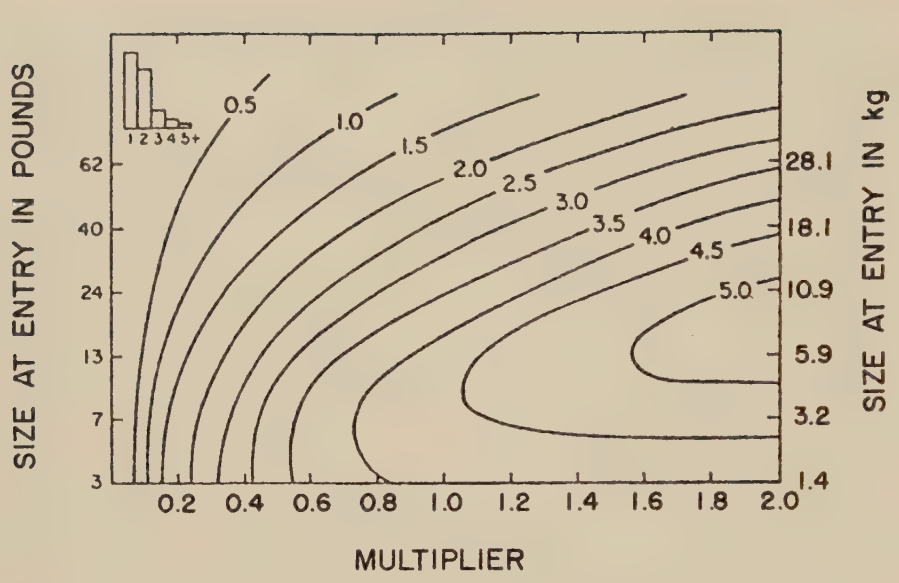


Figure 10. Relationship among size at entry, fishing effort, and Y/R for yellowfin tuna in the eastern tropical Pacific (from SAWS/BP/5)

3.2.6 Recommendations

3.2.6.1 Statistics

The data available for the ETP were considered to be adequate. For the western and central Pacific, much of the necessary data is not available. The group noted that the magnitude and size composition of the large surface catch of the Philippines in recent years should be reliably estimated and historical catch series documented. The problem of double reporting of catches should be addressed and resolved. Estimates of misidentified or unidentified yellowfin tuna in catches must be routinely carried out. Size-composition data are needed for all catches, particularly for the surface fisheries.

3.2.6.2 Research

As already noted, the group recommended that Y/R estimates be undertaken on the western-central stock(s) as soon as possible as well as production model analyses which would include surface catch and effort data. The effects of competition between surface and longline fisheries should be further examined. The extent of mixing between fish available to surface and longline gears should be examined through further tagging studies, particularly in the western Pacific. Additional estimates of yellowfin tuna growth in the western Pacific should also be carried out.

3.3 Pacific Northern Bluefin Tuna (Rapporteurs: Robert A. Skillman and Chiomi Shingu)

The northern bluefin tuna, Thunnus thynnus, occurs both in tropical as well as temperate waters and from the east rim of the Pacific to the west (Figure 11). Transpacific migrations have been recorded. The annual catch of northern bluefin tuna is the smallest among the large tuna species of the Pacific.

A North American purse seine fishery operates off the southern California and northern Baja California coasts predominately in May to October on fish from 60 to 180 cm FL. The four primary Japanese fisheries are conducted virtually year round though the location of the fisheries and the size of the fish captured vary seasonally. The trap net, purse seine, and trolling boat fisheries are conducted along the coast of Japan while the longline fishery is conducted both in coastal waters and also throughout the Pacific.

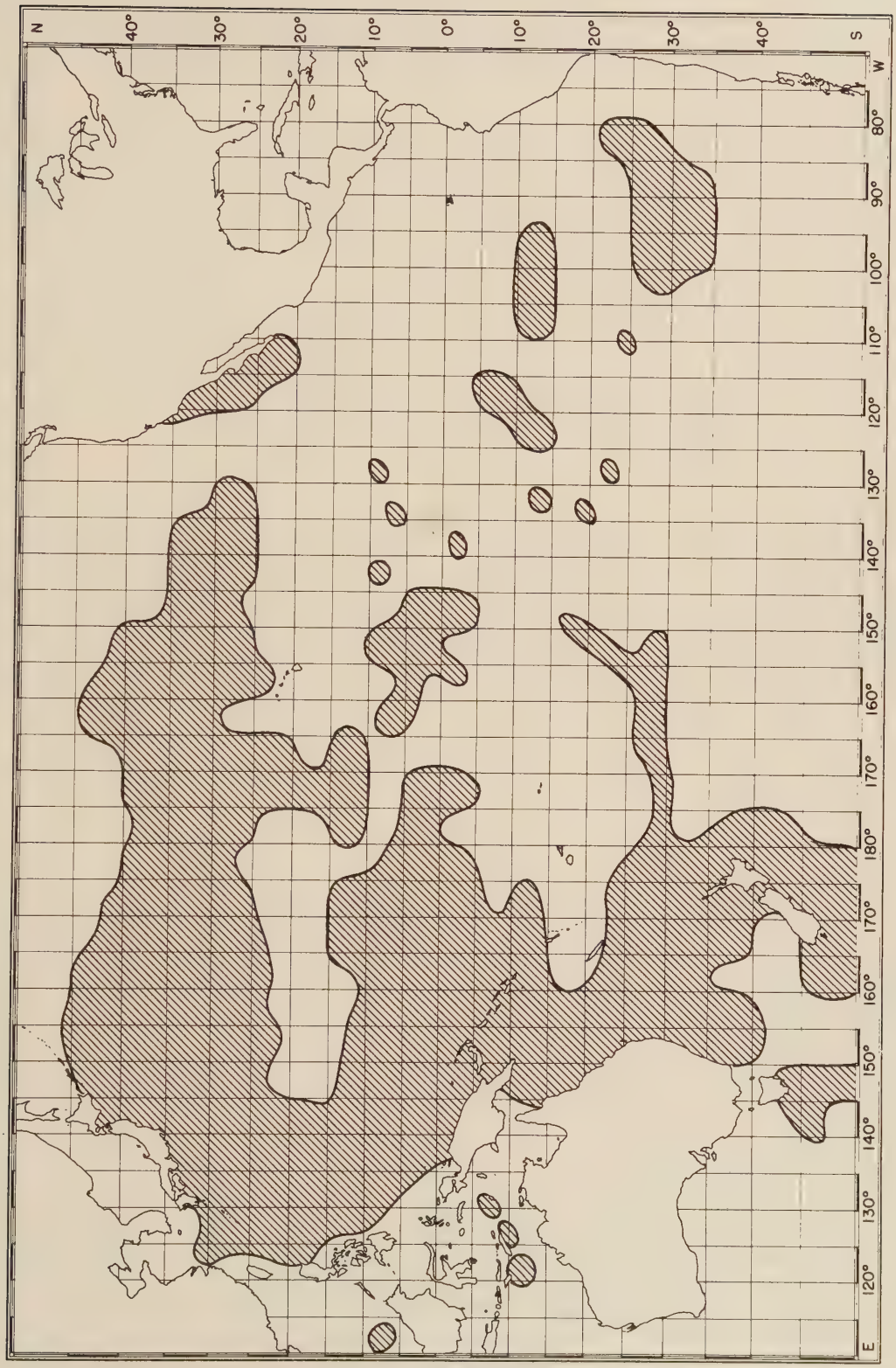


Figure 11. Distribution of northern bluefin tuna in the Pacific (adapted from Figure 2 SAWS/BP/10 and Figure 1 SAWS/BP/9)

3.3.1 Review of current research

The IATTC and the FSFRL are the principal agencies working on northern bluefin tuna in the Pacific. Research consists of monitoring catch trends, collecting size data, conducting age and growth studies based on hard parts (otoliths and scales), and tagging of northern bluefin tuna in Japan and the eastern Pacific.

3.3.2 Review of fishery data

Catch data are available from the eastern Pacific purse seine fishery and from the various Japanese fisheries. Catch data from Taiwan were not presented though they are known to be available. The participants agreed that the longline catches by Korea and Taiwan should be relatively small and that the data presented for the eastern Pacific and Japanese fisheries represent most of the catch. Historically the catch of small tuna by the Japanese fishermen is recorded without regard to species as "meji." Independently acquired market sampling records were used to estimate a catch of 5,000 MT of small northern bluefin tuna in 1978, and such records could be used with due caution to extract the historical catch of northern bluefin tuna from "meji." Some participants expressed a need to verify the reported occurrence of northern bluefin tuna in catches made by Japanese bait boats in warm surface waters off Papua New Guinea and in equatorial waters.

3.3.2.1 Catch trends

The annual catch of northern bluefin tuna in the northwestern Pacific Ocean is presented in Figure 12 and for the ETP in Table 5. Catches in the northwestern Pacific exhibit a great deal of variability. The largest catches occurred in the early years, followed by a marked decline in the late 1950's and then a stable period through the 1960's, and lastly a further decline in the 1970's. The purse seine fishery has accounted for the largest share of the total Japanese catch throughout the years. The catches in the trap and bait boat fisheries were relatively high up to 1956 and since then have declined. The longline fishery has accounted for the smallest share of the total catch but since 1966 the longline catch has shown a slight increase.

The variability in annual catches in the ETP does not appear to have been due to changes in fishing effort (Table 6).

3.3.2.2 Effort trends

Fishing effort statistics for the Japanese purse seine fishery were presented only in terms of the number and type of vessels, and not in detailed fishing units (Table 7). It can be seen that there has been a nearly complete changeover from two-boat seiners to single-boat seiners and that the total carrying capacity has increased while the number of boats decreased slightly. The number of trap nets for the main fishing areas is presented in Table 8. No discernible trend is apparent though there are large changes in some areas.

Crude fishing effort data for the eastern Pacific purse seine fishery (Table 6) do not demonstrate any historical trends, although the number of boats has increased.

3.3.2.3 Trends in catch per unit effort

No CPUE statistics for northern bluefin tuna in the Japanese fisheries were presented.

For the eastern Pacific purse seine fishery, CPUE data were prepared by selecting months when bluefin tuna catches occurred. These data are believed to give a general trend of local abundance. No trend is apparent though the greatest catches occurred in 1971 through 1976 (Table 6).

3.3.3 Stock structure

Based on (1) the occurrence of sexually mature fish and larvae in the western Pacific

and the absence of same in the eastern Pacific, (2) the recapture of two fish in the eastern Pacific from a small number of fish tagged off Japan, and (3) the recapture of nine fish off Japan from a larger pool of fish tagged in the eastern Pacific, it is believed that there is a single stock of northern bluefin tuna in the Pacific.

3.3.4 Population parameters

Published estimates of northern bluefin tuna population parameters (SAWS/BP/1) were discussed. Length-weight relationships, von Bertalanffy growth parameters, and estimates of instantaneous mortality coefficients and fecundity were compared with estimates for Atlantic northern bluefin tuna.

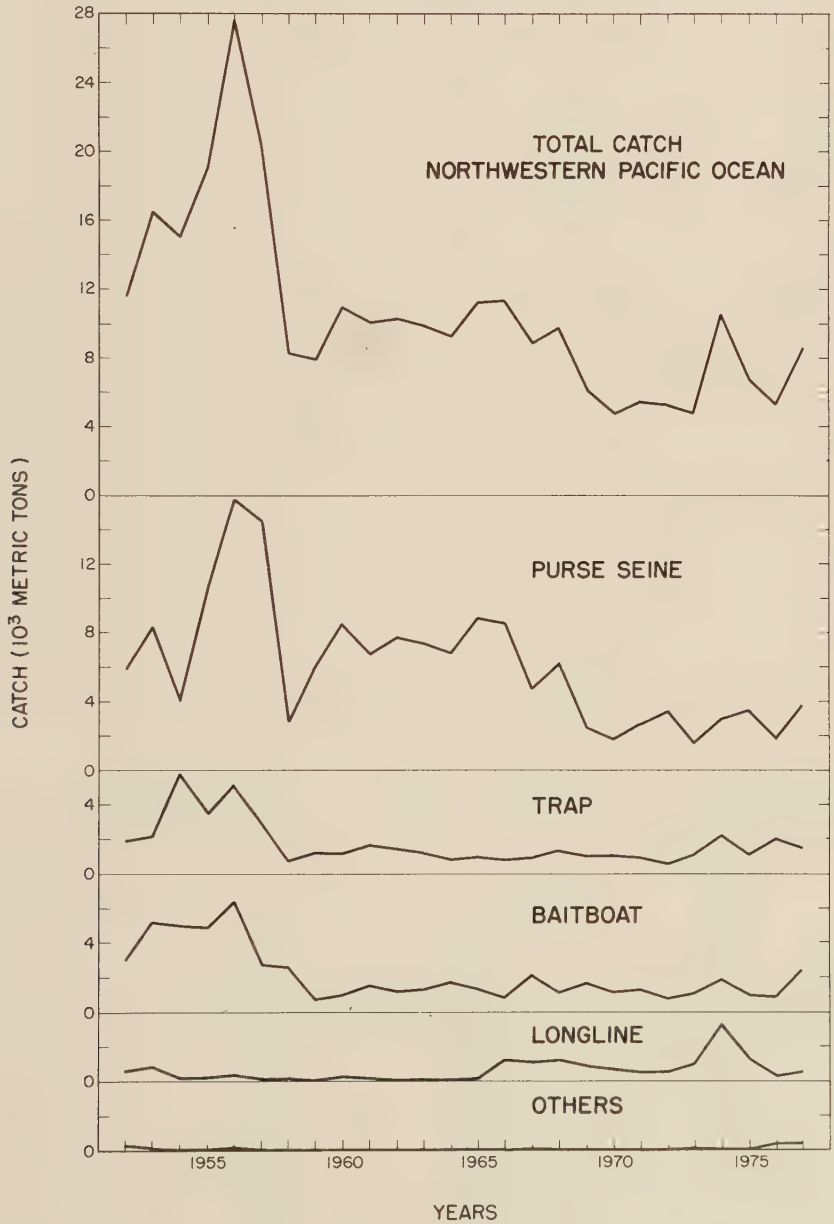


Figure 12. Annual catch of northern bluefin tuna by gear from the northwestern Pacific Ocean, 1952-77 (from SAWS/BP/10). (Does not include catch lumped in "meji" category.)

TABLE 5. Annual surface catches of northern bluefin tuna by commercial vessels, in metric tons, in the eastern Pacific Ocean. The value for 1978 is preliminary (from SAWS/BP/9)

Year	Catch	Year	Catch
1918	2,722	1949	1,991
1919	6,800	1950	1,242
1920	4,776	1951	1,752
1921	894	1952	2,076
1922	1,275	1953	4,433
1923	1,460	1954	9,537
1924	1,470	1955	6,173
1925	1,725	1956	5,727
1926	2,960	1957	9,215
1927	2,222	1958	13,934
1928	6,215	1959	6,914
1929	3,414	1960	5,422
1930	9,943	1961	9,603
1931	1,603	1962	14,651
1932	486	1963	14,189
1933	254	1964	10,642
1934	8,327	1965	7,556
1935	11,418	1966	16,846
1936	8,584	1967	6,601
1937	5,758	1968	6,063
1938	8,041	1969	7,172
1939	5,369	1970	4,024
1940	9,058	1971	8,415
1941	4,318	1972	13,390
1942	5,826	1973	10,576
1943	4,617	1974	5,748
1944	9,228	1975	9,578
1945	9,341	1976	10,561
1946	9,993	1977	5,151
1947	9,452	1978	5,325
1948	2,961		

TABLE 6. Logged northern bluefin tuna catch, effort, and catch per day's fishing in the eastern Pacific, 1967-78 (from SAWS/BP/9)

Year	Months used	Days fishing	Catch	Catch per day's fishing
1967	6-9	3,631	5,166	1.42
1968	6-10	2,408	4,980	2.07
1969	5-9	2,981	5,837	1.96
1970	6-8	2,209	3,786	1.71
1971	5-10	3,525	7,449	2.11
1972	5-10	3,694	11,919	3.23
1973	6-9	2,514	7,261	2.88
1974	6-9	2,203	3,854	1.75
1975	6-10	2,333	6,359	2.72
1976	5-10	2,969	8,926	3.00
1977	5-10	2,504	4,655	1.86
1978	6-9	2,315	3,749	1.62

TABLE 7. Number of tuna purse seiners by type and size in the Japanese northern bluefin tuna fishery in the Pacific, 1969-77 (from SAWS/BP/10)

	Single boat					Two boats			
	Boat capacity in tons					Boat capacity in tons			
Year	50-100	100-200	200-500	>500	Subtotal	30-50	50-100	Subtotal	Total
1969	--	12	4	--	16	3	52	55	71
1970	--	15	6	--	21	2	47	49	70
1971	1	22	6	--	29	2	39	41	70
1972	2	29	7	--	38	1	33	34	72
1973	1	36	6	--	43	2	17	19	62
1974	2	40	9	1	52	1	11	12	64
1975	3	39	10	2	54	--	10	10	64
1976	3	40	13	2	58	--	10	10	68
1977	3	47	12	2	64	--	1	1	65

3.3.5 Status of stocks

At the present time it is not possible to make meaningful assessments of the northern bluefin tuna stock. If catches from the two major fisheries are combined and a reliable measure of fishing effort obtained, a simple production model assessment could be attempted; however, the participants felt that if representative size composition data became available a cohort analysis might be more productive.

3.3.6 Effects of regulation

No regulations are in effect.

3.3.7 Recommendations

3.3.7.1 Statistics

For the Japanese fisheries, the catch of small northern bluefin tuna should be reported separately rather than included in "meji" or small tunas.

Size-composition data should be collected for all gears, and these data should preferably be in length, not weight. Since the seasonal variation in weight of individual northern bluefin tuna is substantial, size samples based on weight would need to be taken monthly.

3.3.7.2 Research

Further attempts to age northern bluefin tuna using hard parts should be encouraged. The occurrence of northern bluefin tuna in parts of the South Pacific should be verified.

TABLE 8. Number of trap nets in the main landing areas (prefectures) of northern bluefin tuna in Japan (from SAWS/BP/10)

Prefecture	1955		1960		1965		1970		1975		1977	
	Large	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large	Small
Pacific												
Iwate	132	218	97	188	91	133	86	110	76	99	66	89
Mie	62	242	50	274	--	--	40	275	41	334	41	355
Wakayama	83	39	13	34	9	19	9	25	9	24	9	21
The Sea of Japan												
Hokkaido	268	2,371	110	2,086	45	1,753	53	1,055	92	1,340	203	1,441
Aomori	10	254	8	196	12	350	11	199	11	279	11	453
Akita	12	356	12	794	9	699	7	614	7	677	8	809
Yamagata	--	76	3	82	3	38	--	90	--	43	--	57
Niigata	33	272	30	175	25	190	33	198	30	243	31	220
Toyama	81	54	105	66	71	56	69	58	70	67	64	63
Fukui	36	356	38	257	33	214	32	255	35	194	31	220
Kyoto	46	99	45	125	29	48	27	136	22	162	24	143
Total	763	4,337	511	4,277	327	3,500	367	3,015	393	4,362	488	3,871

3.4 Pacific Bigeye Tuna (Rapporteurs: Robert E. Kearney and Susumu Kume)

Bigeye tuna, Thunnus obesus, are widely distributed in the temperate and tropical waters of the Pacific between about lat. 45°N and 40°S (Figure 13). Catch rates in the longline fishery indicate at least two east-west zonal bands of high abundance, one in the North Pacific centered at around lat. 30°N in the winter and the other in the equatorial area. In the equatorial area the east-west zone of high abundance is almost continuous; however, east of long. 150°W, another zone of high abundance is located further south along lat. 10°S.

Longline gear accounts for more than 90% of the reported total bigeye tuna catch in the Pacific. Small amounts of bigeye tuna are taken in the Japanese surface fishery for skipjack tuna and albacore in the northwestern Pacific. Bigeye tuna are also caught by purse seiners in the ETP fishery for yellowfin tuna and skipjack tuna.

3.4.1 Review of current research

At the present time, research on bigeye tuna is largely restricted to limited studies being carried out in Japan. Previous studies which have been limited to work on the size at first maturity, growth, sexual dimorphism, and length-weight relationships are reviewed in SAWS/BP/6.

3.4.2 Review of fishery data

3.4.2.1 Catch trends

Total catches of bigeye tuna in the Pacific from 1952 to 1977 increased steadily through the 1950's and early 1960's before peaking at about 150,000 MT in 1963. The catches declined thereafter and fluctuated between 70,000 and 107,000 MT until 1975. They increased again to more than 140,000 MT in 1976 and 1977 (Table 9 and Figure 14). Most of the fluctuations in total recorded catch are attributable to changes in catches by the Japanese longline fleet; however, the Korean longline catch increased from 2,500 MT to about 21,400 MT during the 1970's and the catches in the eastern Pacific purse seine fishery increased sharply from about 2,000 MT to about 10,000 MT in 1976 and 1977.

3.4.2.2 Effort trends

The total longline fishing effort for Pacific bigeye tuna increased fivefold from 1957 to 1977 (Table 10). During this period there was a general spread of longlining effort over the Pacific between lat. 45°N and 40°S and two major phases in the increase in effort are detectable. Firstly, in the early 1960's the fishery in the ETP developed, resulting in substantial increases in both effort and catch. Secondly, during 1974-77 there was an increase in the use of deep longline gear for bigeye tuna. The longline gear was made to fish deeper by increasing the length of line between floats and coincidentally the number of hooks per basket. The shift to this type of gear is clearly visible (Figure 15).

3.4.2.3 Trends in catch per unit effort

Between 1957 and 1977 the total catch of Pacific bigeye tuna per million hooks of effort decreased from 568 to 213 MT (Table 10). The average size of the fish taken in the major fishing areas fluctuated between 1955 and 1976 (Figure 16) and this played a major role in the elevated total landings in the early 1960's. Furthermore the changes to deep-water longlining may have affected fishing efficiency from 1975 more than has been estimated. Of interest is that if the catch rate (MT/10^6 hooks) and total effort, were averaged over a 3-yr period, and plotted, the marked fluctuations in the 1960's and middle 1970's would be largely masked and a smoother declining trend would result.

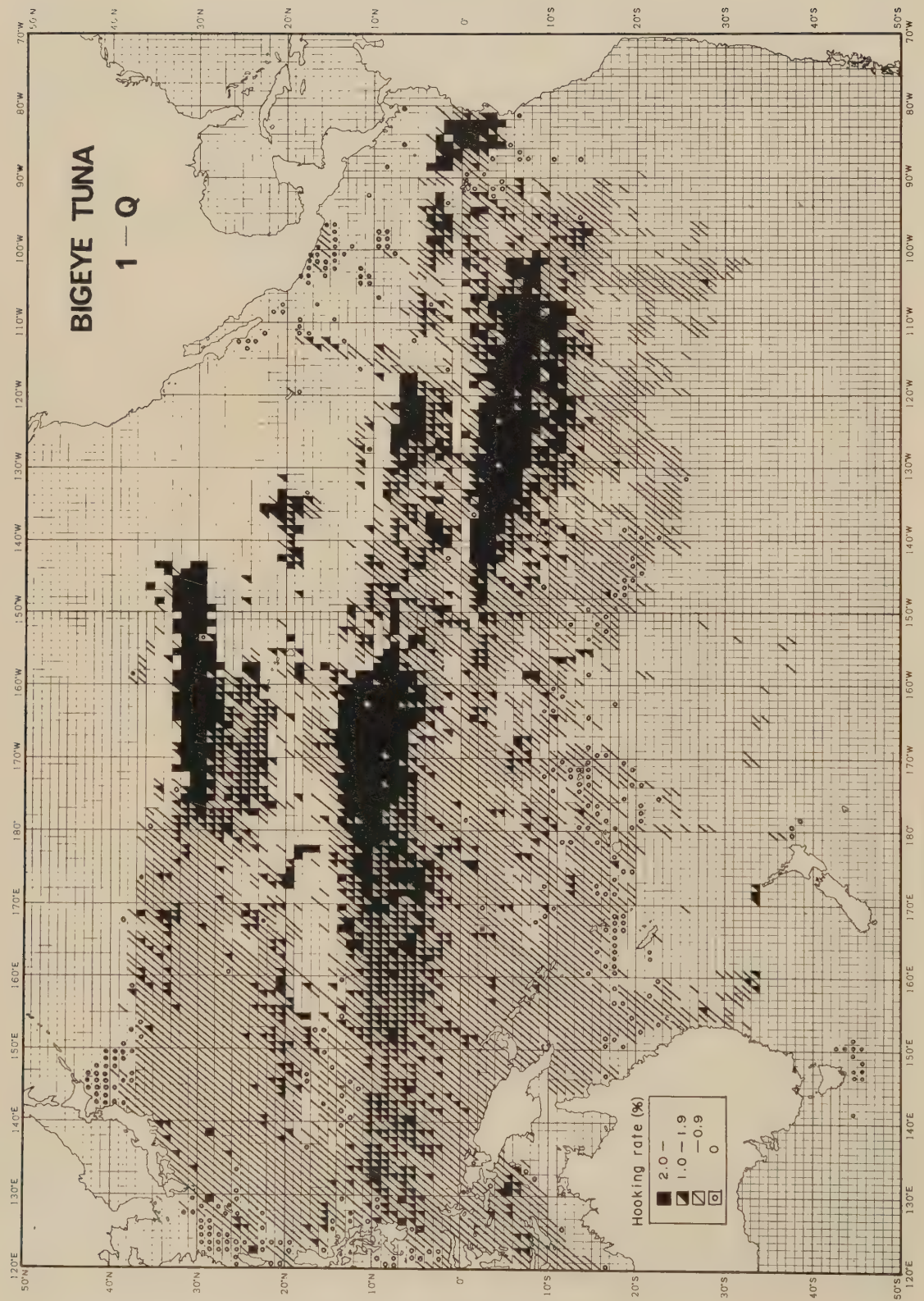


Figure 13. Quarterly distribution of bigeye tuna in the Pacific Ocean expressed by average catch rates in the Japanese longline fishery (from SAWS/BP/6)

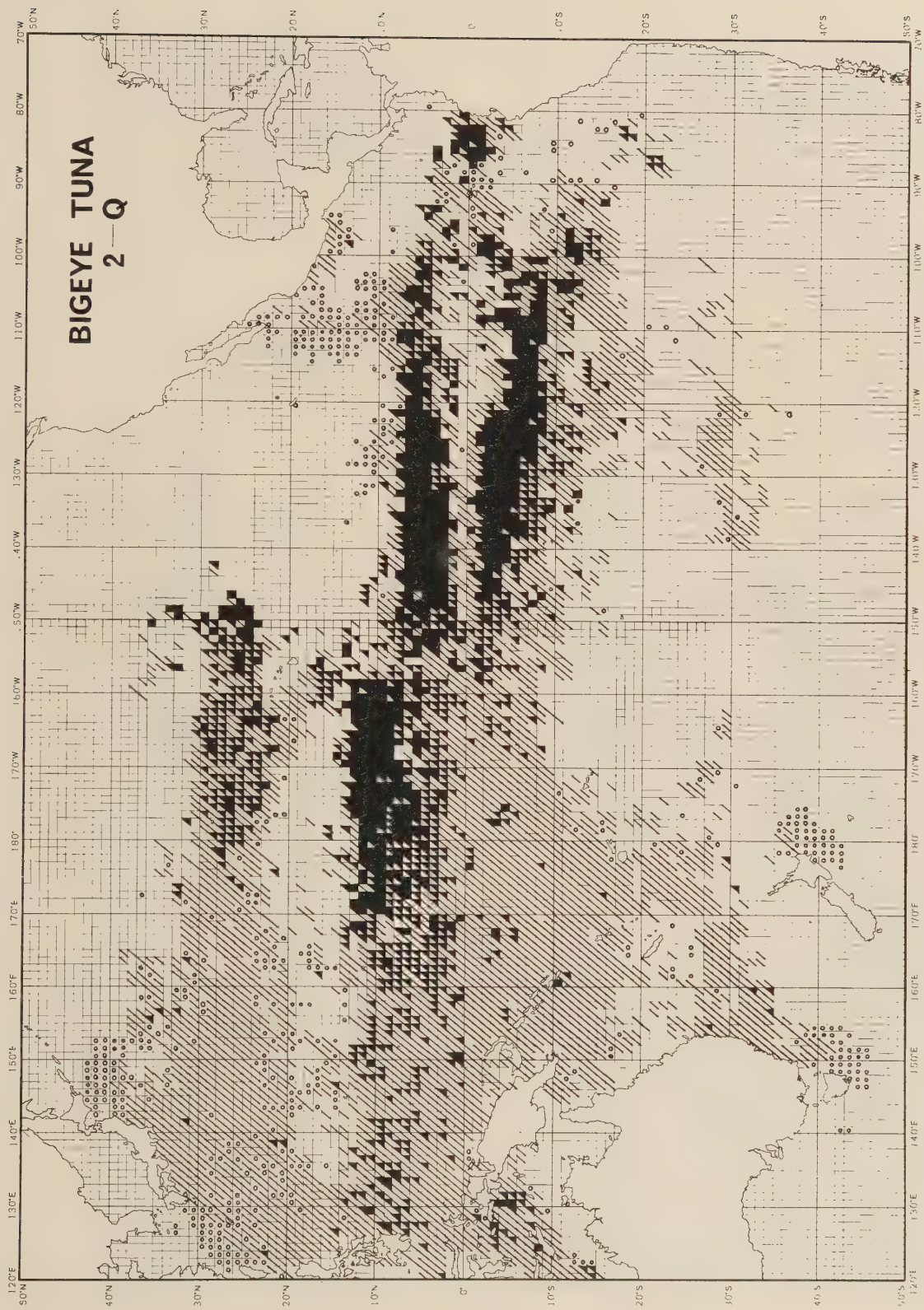


Figure 13. Continued

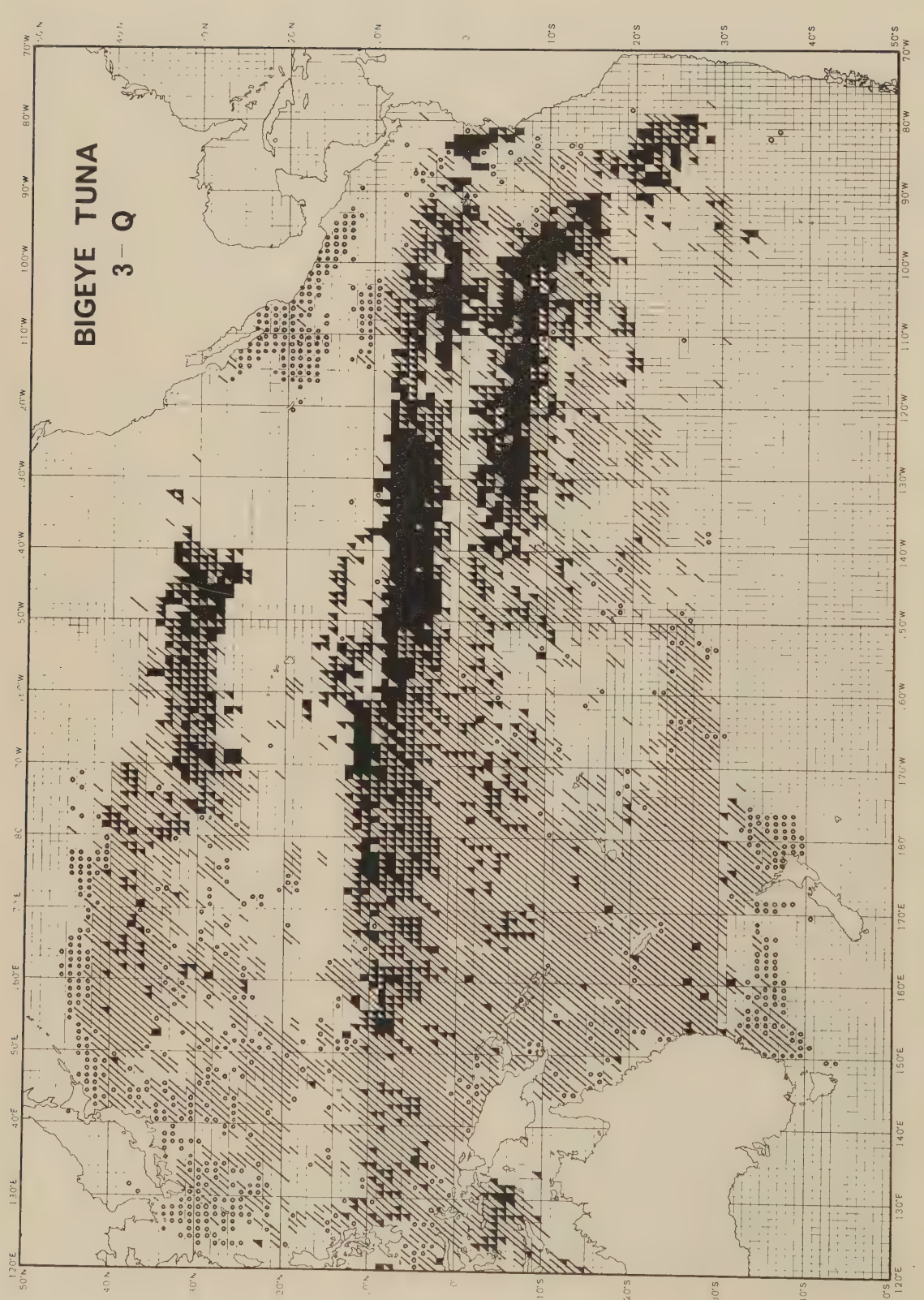


Figure 13. Continued

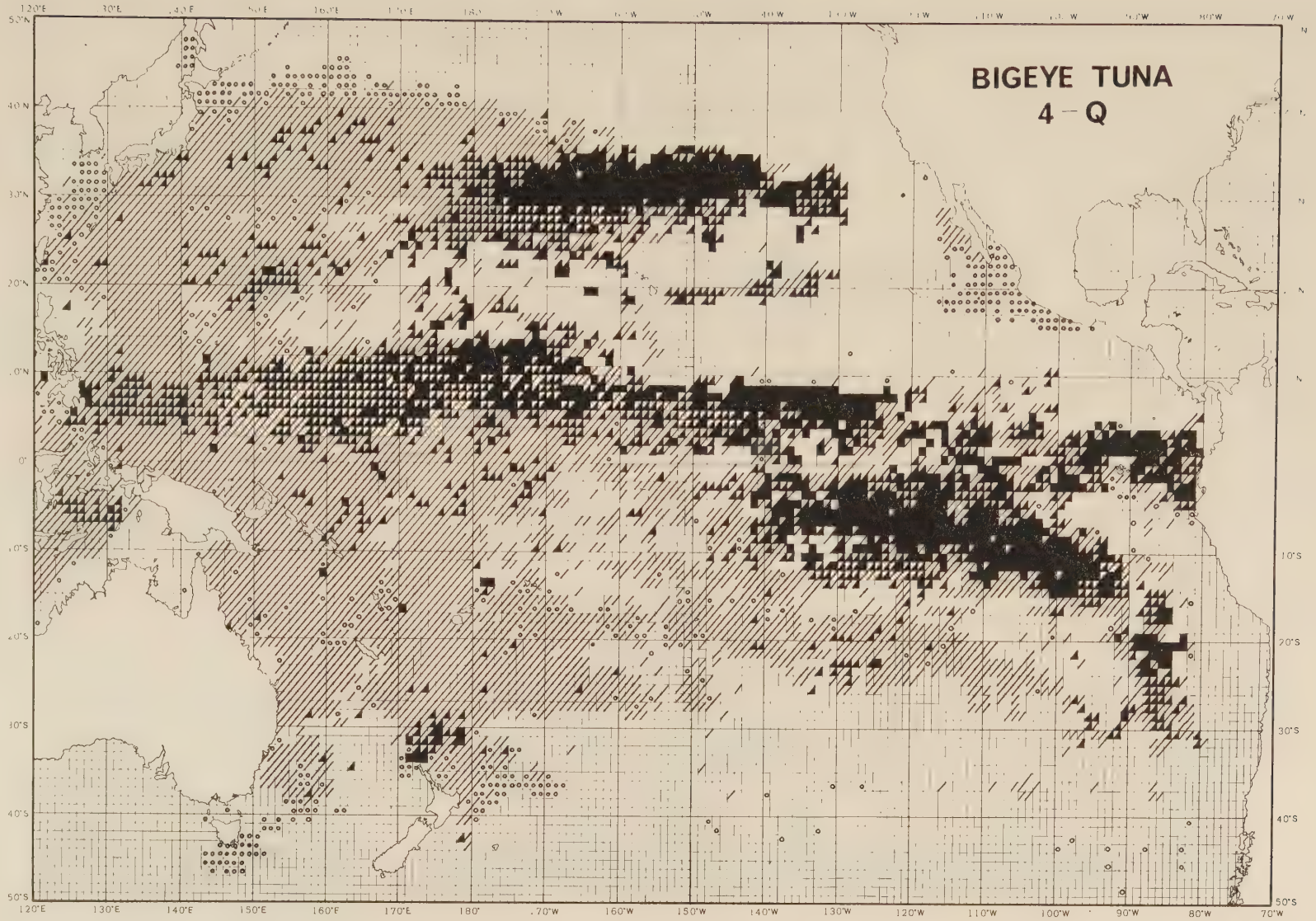


Figure 13. Continued

TABLE 9. Estimated annual catch of bigeye tuna in the Pacific Ocean, 1952-77 (from SAWS/BP/6)

	Longline				Bait boat	Purse seine		
Year	Japan	Taiwan	Korea	Subtotal	Japan	Japan	Eastern tropical Pacific	Total
				(Thousand metric tons)				
1952	26.5			26.5	2.1	1.0		29.6
1953	22.4			22.4	2.4	0.6		25.4
1954	26.2	0.4		26.6	2.1	0.4		29.1
1955	[1]39.2	0.8		40.0	4.0	0.3		44.3
1956	[1]30.7	0.9		31.6	4.4	0.9		36.9
1957	64.4	0.9		65.3	5.2	0.0		70.5
1958	86.5	1.0		87.5	4.2	0.0		91.7
1959	79.3	0.8		80.1	1.7	0.0		81.8
1960	87.6	0.7		88.3	1.5	0.1		89.9
1961	132.2	1.5		133.7	1.8	0.1		135.6
1962	119.8	3.4		123.2	0.8	0.2		124.2
1963	144.4	3.6		148.0	1.8	0.0		149.8
1964	99.5	3.5		103.0	1.1	0.2		104.3
1965	73.5	3.4	0.7	77.6	1.3	0.2		79.1
1966	76.9	3.0	2.9	82.8	1.1	0.0		83.9
1967	77.7	3.4	3.2	84.3	2.8	0.1	1.5	88.7
1968	63.8	4.2	0.6	68.6	2.3	0.2	2.5	73.6
1969	91.4	3.4	2.5	97.3	1.7	0.1	0.6	99.7
1970	70.6	2.8	2.5	75.9	1.6	0.2	1.3	79.0
1971	64.5	3.5	4.7	72.7	0.9	0.2	2.5	76.3
1972	81.9	4.9	7.8	94.6	2.4	0.8	2.2	100.0
1973	89.4	5.7	8.9	104.0	0.9	0.2	2.0	107.1
1974	82.0	4.2	14.4	100.6	0.7	0.4	0.9	102.6
1975	85.2	5.2	15.5	105.9	3.5	0.5	3.9	113.8
1976	102.2	2.9	21.4	126.5	4.4	0.6	10.4	141.9
1977	105.7	2.6	17.7	126.0	4.0	0.8	9.6	140.4

[1]Preliminary.

3.4.3 Stock structure

The stock structure of Pacific bigeye tuna is not clear. The occurrence of major spawning activity in the eastern Pacific and the simultaneous appearance of a dominant year class over a wide area support the unit stock hypothesis. However, the occurrence of at least some localized spawning activity and the presence of a cline in modal lengths in the North Pacific suggest multiple stocks (SAWS/BP/6).

3.4.4 Population parameters

Published estimates (SAWS/BP/1) of various parameters were reviewed but no new information could be added.

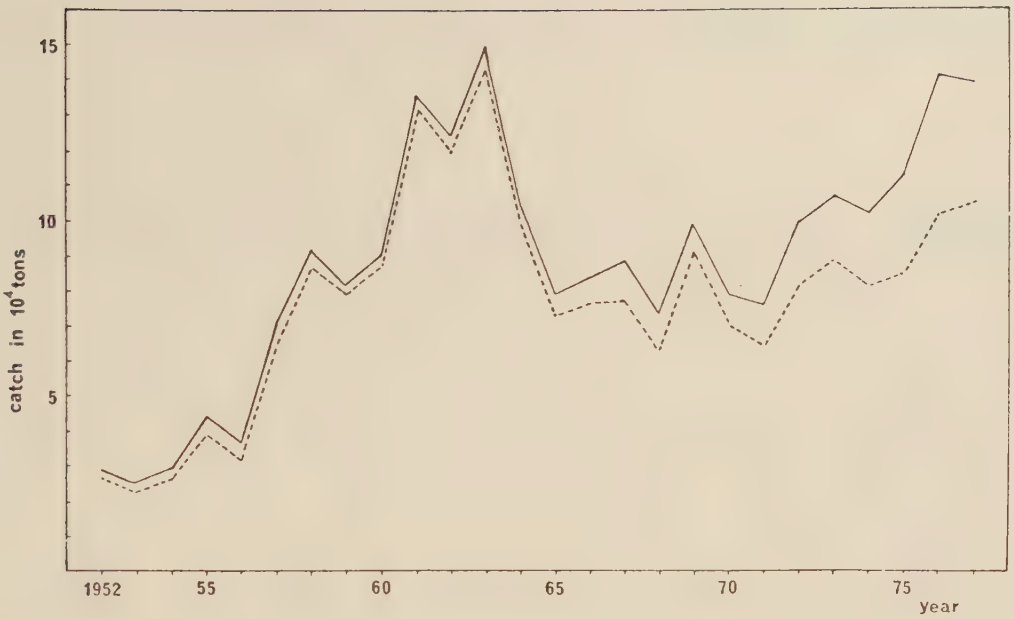


Figure 14. Annual bigeye tuna catch in the Pacific Ocean, 1952-77. Dotted line represents Japanese longline catch (from SAWS/BP/6)

TABLE 10. Estimated catch and effort statistics for bigeye tuna caught by the longline fishery in the Pacific Ocean, 1957-77. The effort data for 1975-77 were adjusted for deep longline fishing (from SAWS/BP/6)

Year	Japanese fleet		Total catch (10^3 tons)	Estimated total effort (10^6 hooks)	Catch rate (MT/10^6 hooks)
	Effort (10^6 hooks)	Catch (10^3 tons)			
1957	113	63.9	65.3	115	568
1958	140	86.0	87.5	142	616
1959	155	78.8	80.1	158	507
1960	170	87.1	88.3	172	513
1961	231	131.7	133.7	235	569
1962	254	119.3	123.2	262	470
1963	342	143.9	148.0	352	420
1964	292	99.0	102.9	304	338
1965	260	73.0	77.6	276	281
1966	258	76.4	82.8	280	296
1967	267	77.2	84.3	292	289
1968	251	63.3	68.6	272	252
1969	318	90.9	97.3	340	286
1970	298	70.0	75.9	323	235
1971	274	63.9	72.7	312	233
1972	311	81.1	94.5	362	261
1973	345	88.5	104.0	405	257
1974	328	80.9	100.6	408	246
1975	332	83.0	105.9	424	250
1976	422	99.4	126.5	537	236
1977	485	103.2	126.0	592	213

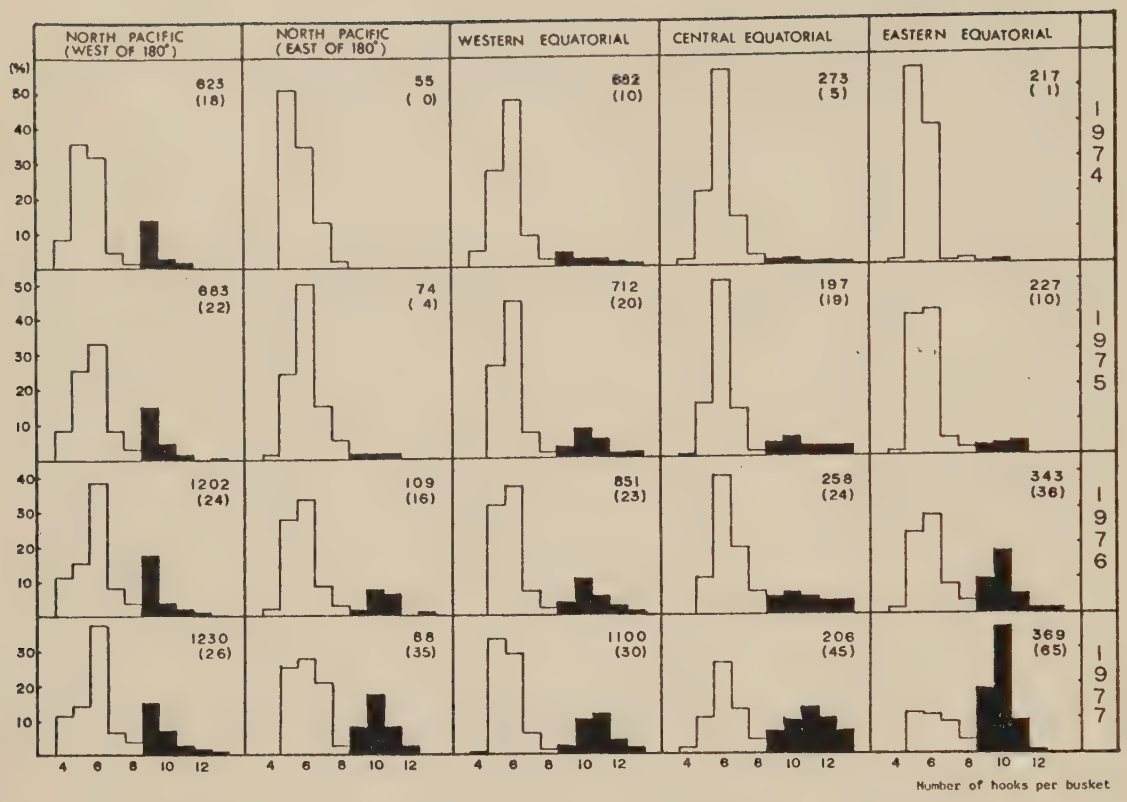


Figure 15. Frequency distribution of type of longline gear (number of hooks per basket) used by Japanese longliners in the Pacific Ocean by area. Figures in the panel show the number of trips and figures in the parentheses the percentage of the deep longline gear (shaded area) (from SAWS/BP/6)

3.4.5 Status of stocks

3.4.5.1 Production model analysis

A production model analysis based on the single stock hypothesis and using total longline catch and Japanese catch and effort data has been carried out (Figure 17). The limitations of this model, particularly with regard to the change to deep fishing longline gear must be borne in mind. Furthermore, the decrease in CPUE with time was reasonably regular (Figure 18), but the relationship of total catch in weight to total effort appeared to be definitely biphasic (Figure 17).

3.4.5.2 Yield-per-recruit analysis

No analyses were possible.

3.4.5.3 Recruitment analysis

There is insufficient data to enable recruitment analyses to be done at this time. Very little is known about recruitment into the longline fishery which accounts for the greatest part of the catch of this species. Most of the longline catch is of larger, adult fish and while juveniles are taken in the surface pole-and-line and purse seine fisheries, the number of juveniles caught is small; 126,000 MT of bigeye tuna are taken in the longline fishery and only 14,400 MT, much of which are juveniles, in surface fisheries. By comparison

110,000 MT (adults) of Pacific yellowfin tuna are taken by longlining and 280,000 MT (adults plus juveniles) by surface fisheries. This suggests that additional young bigeye tuna may be taken if surface fisheries can be developed.

3.4.5.4 Current appraisal

The present state of exploitation of the stocks cannot be accurately assessed. It appears that further increases in the effective longline fishing effort could still increase the total catch at the expense of further declines in the CPUE. Very few bigeye tuna are presently taken in surface fisheries. If catches of juvenile bigeye tuna are to be substantially increased, then new fisheries would need to be developed, probably in areas not presently being fished by tuna vessels. Nothing is known of the interaction between surface and longline fisheries for this species.

3.4.6 Effects of regulations

There are no regulations on the capture of this species in the Pacific Ocean.

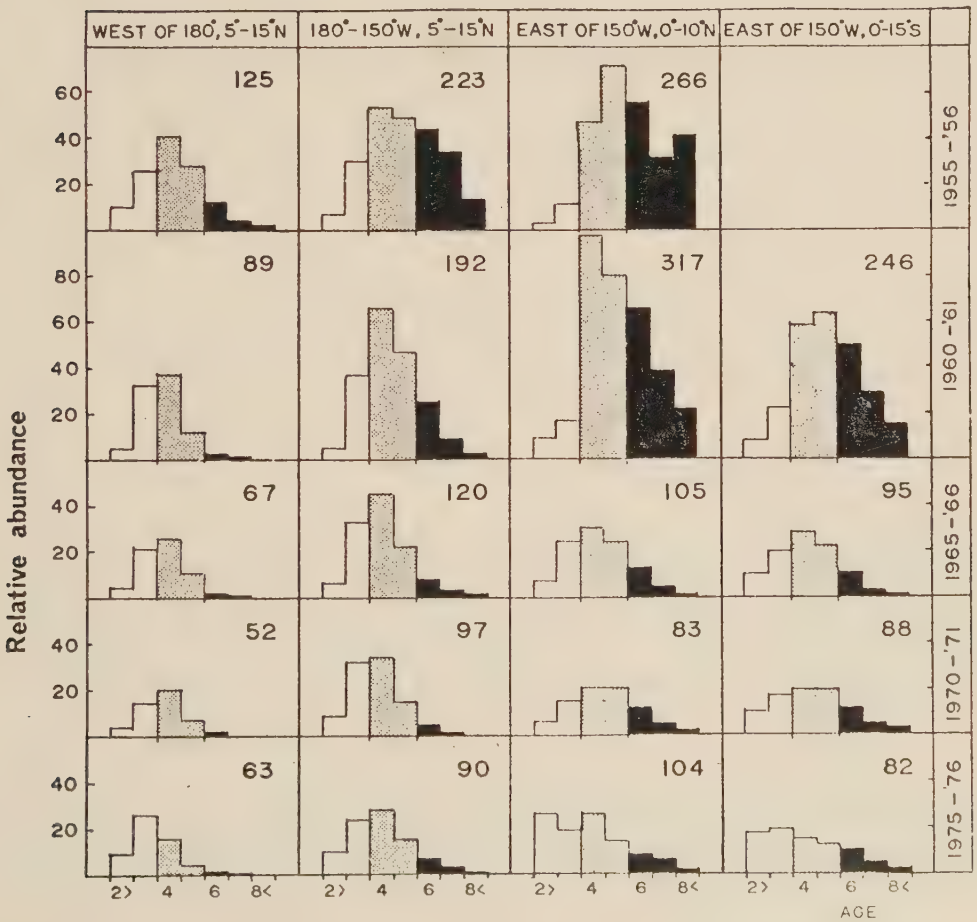


Figure 16. Relative abundance of bigeye tuna in the equatorial Pacific, by age and 5-yr intervals. Figures in the panels are total relative abundance (catch rate) (from SAWS/BP/6)

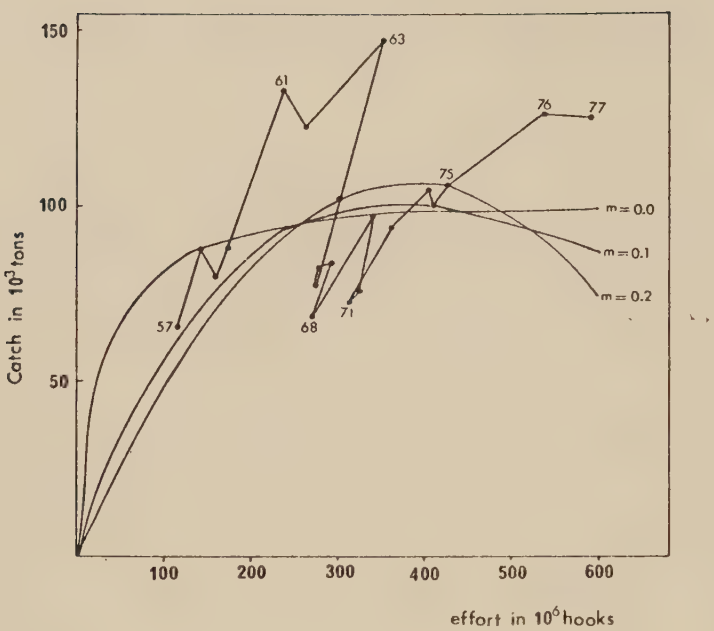


Figure 17. Sustainable average yield curves from production model analysis and observed catches of bigeye tuna caught by the longline fishery in the Pacific Ocean, 1957-77 (from SAWS/BP/6)

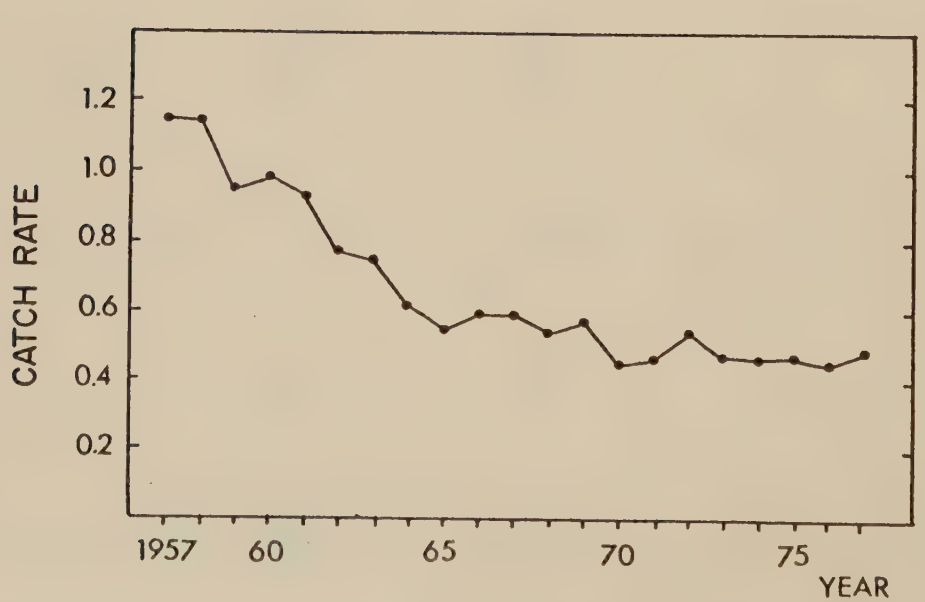


Figure 18. Annual change in overall catch rate (number per 100 effective hooks) of bigeye tuna in the Pacific Ocean, estimated from Japanese data, 1957-77 (from SAWS/BP/6)

3.4.7 Recommendations

3.4.7.1 Statistics

It is recognized that the availability of detailed data on the longline fishery, except for the Japanese fleet, should be improved. The problem with the surface fishery statistics for this species relates to the underestimation of the catch of juveniles due to nonreporting or misidentification of catches. Attempts should be made to obtain more accurate figures on the total catches and size composition of the catch in the surface fisheries.

3.4.7.2 Research

The possibility that growth rates of bigeye tuna are different throughout the Pacific should be investigated if possible. Certainly the differences in size composition of bigeye tuna in the catches across the Pacific needs to be reexamined. A reanalysis of the changes in the longline catches of bigeye tuna by numbers and weight and by areas of the Pacific should be carried out.

The impact of the change to deep longlining should be carefully monitored.

3.5 South Pacific Albacore (Rapporteurs: Gary T. Sakagawa and Bong Yeoul Kim)

The longline fishery for albacore, Thunnus alalunga, in the South Pacific is carried out over a wide area from about long. 135°E to 80°W between equatorial waters and about lat. 45°S (Figure 19). In recent years the Japanese catch of albacore in the South Pacific has been made by home-based longliners, whereas most of the albacore catch of longliners from Korea and Taiwan have been made by vessels based at American Samoa or other foreign ports. Small quantities of albacore are taken in surface fisheries in Chile and New Zealand.

3.5.1 Review of current research

One background paper (SAWS/BP/8) presented an evaluation of the status of the South Pacific albacore stock including a production model analysis, the development of an improved abundance index, and an age-structured simulation model.

3.5.2 Review of fishery data

3.5.2.1 Catch trends

The general trend in the annual albacore catch from 1952 through 1977 was a rapid rise from 200 MT in 1952 to 24,000 MT in 1960, followed by a period of large fluctuations around an average of about 35,000 MT (Table 11 and Figure 20). Peaks in the catches occurred in 1962, 1967, and 1973, and lows in 1964, 1969, and 1975. Although the fluctuations were in part caused by changes in the fishing areas, the primary cause was changes in fishing effort (Table 12).

3.5.2.2 Effort trends

During 1954 to 1963, Japanese longliners constituted a large portion of the longline fleet fishing for albacore in the South Pacific. Since then, the Japanese fleet has decreased while the Taiwan and Korean fleets have increased (Table 11). The net effect has been the maintenance of effective fishing effort at a high level (Figure 20).

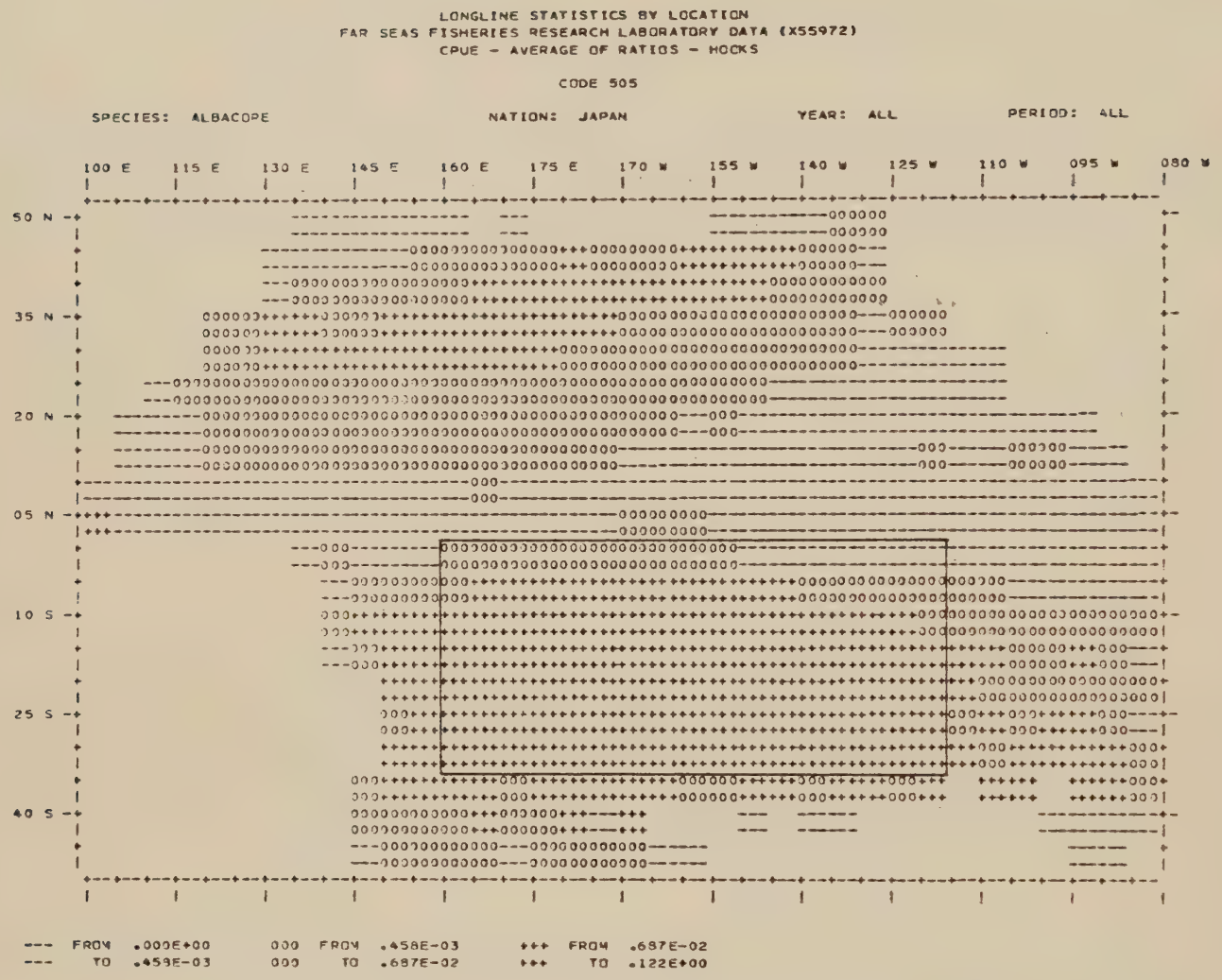


Figure 19. Distribution of average catch per hook for Pacific Ocean albacore taken by Japanese longliners, averaged over 1952-76. Boundaries of the index area for the South Pacific albacore stock are also shown (from SAWS/BP/8)

3.5.2.3 Trends in catch per unit effort

Catch per unit effort statistics from logbooks of Japanese, Taiwan, and Korean longline vessels landing in American Samoa have been compiled and standardized (SAWS/BP/8). An average CPUE was then computed that was assumed to reflect actual abundance or size of the exploitable albacore stock (Figure 20) and was used as the most reliable index of abundance.

The abundance index was high in 1962 and then declined steadily to a low of 14 kg/100 hooks in 1975. Since 1975, the index has increased reaching 22 kg/100 hooks in 1977, the most recent year for which data were available. It is believed that this increase is not related to changes in efficiency of longlining owing to the introduction of the deep longlining technique, but is related to an increase in stock abundance. Both the Taiwan and Korean fleets, which landed the bulk of the catch since 1968, do not appear to have extensively adopted the deep longline technique, which is being used increasingly by Japanese longliners.

TABLE 11. Estimated total catches (metric tons) of South Pacific albacore, 1952-77 (from SAWS/BP/8)

Year	Japan	Taiwan	Japan and Taiwan	Korea	Other	Total
1952	210	--	210	--	--	210
1953	1,091	--	1,091	--	--	1,091
1954	10,200	--	10,200	--	--	10,200
1955	8,420	--	8,420	--	--	8,420
1956	6,220	--	6,220	--	--	6,220
1957	9,764	--	9,764	--	--	9,764
1958	21,558	--	21,558	146	--	21,704
1959	19,344	--	19,344	456	--	19,800
1960	23,756	--	23,756	610	--	24,366
1961	25,628	--	25,628	330	--	25,958
1962	38,880	0	38,880	599	--	39,479
1963	33,500	608	34,108	1,367	--	35,475
1964	21,435	629	22,064	2,911	--	24,975
1965	19,305	1,640	20,945	6,405	100	27,450
1966	23,401	6,669	30,070	10,817	500	41,387
1967	16,640	14,910	31,550	13,717	105	45,372
1968	7,707	14,496	22,203	10,138	14	32,355
1969	5,559	9,883	15,442	9,963	--	25,405
1970	6,560	12,463	19,023	11,599	50	30,672
1971	4,339	21,584	25,923	14,482	200	40,605
1972	2,796	23,050	25,846	14,439	468	40,753
1973	2,381	28,858	31,239	17,452	584	49,275
1974	1,847	19,980	21,827	12,194	890	34,911
1975	1,045	15,092	16,137	9,015	1,827	26,979
1976	1,906	19,954	21,860	12,212	2,462	36,534
1977	2,240	21,345	23,585	13,176	4,610	41,371

3.5.3 Stock structure

The current accepted hypothesis of albacore stock structure in the Pacific Ocean is that there are at least two stocks, one or two in the North Pacific and another in the South Pacific. This hypothesis is based on circumstantial evidence including: (1) Pacific-wide catch rates of longline vessels show high catch rates in the higher latitudes separated by low catch rates at the equator (Figure 19) and (2) albacore tagged in the North Pacific have not been recovered in the South Pacific. Albacore in the South Pacific are assumed to be of a single unit stock, confined to the Southern Hemisphere.

3.5.4 Population parameters

Workshop participants reviewed the available population parameters for South Pacific albacore (SAWS/BP/1). Estimates are lacking or are poor for many population parameters. Estimates of age and growth are required because they would provide more accurate data on the age composition of the catch which would allow the application of more powerful assessment techniques.

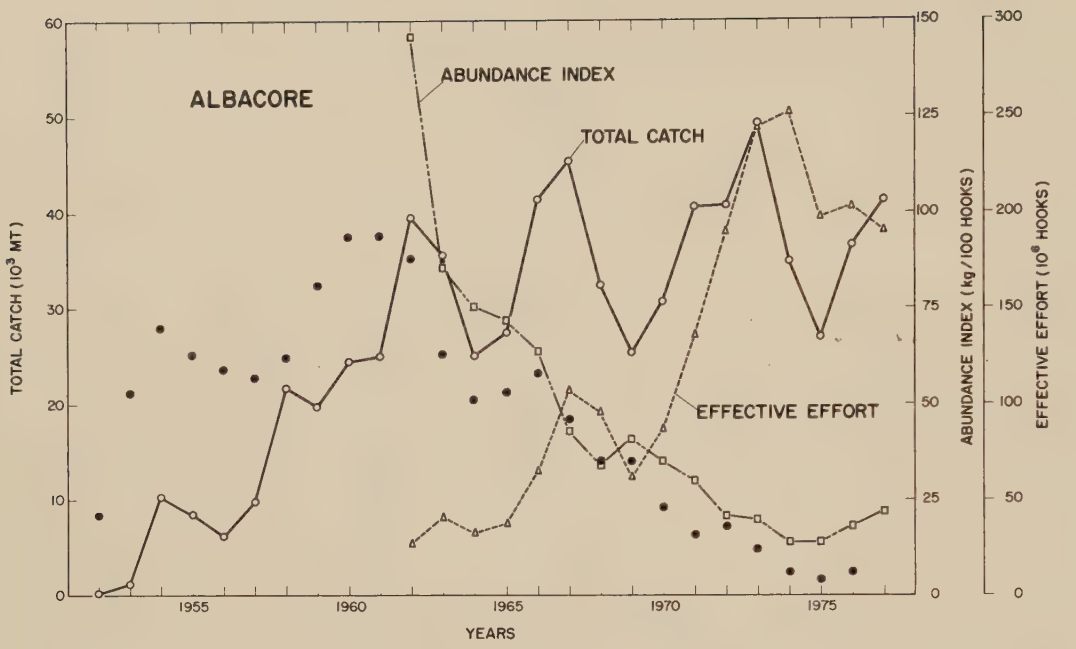


Figure 20. Estimated total catch (10^3 MT), abundance index (kg/100 hooks), and effective effort (10^6 hooks) for South Pacific albacore. Solid circles denote a second index of abundance based on historical Japanese longline statistics (from SAWS/BP/8)

3.5.5 Status of stocks

3.5.5.1 Production model analysis

A generalized production model was used to assess the condition of the South Pacific albacore resource (SAWS/BP/8). The analysis was based on total catch statistics (Table 11) and effective fishing effort which were estimated by dividing total catch by the abundance index (Figure 20).

Results of the analysis indicate a fairly flat yield curve over a broad range of effort (Figure 21). The MSY from the longline fishery is between 33,000 and 36,000 MT with a predicted optimum effective effort level of 60×10^6 hooks to 339×10^6 hooks (SAWS/BP/8). According to the model, virtually no increase in yield to longliners can be expected with increase in effort above the 1977 level and in fact, a substantial reduction in effort would not, on the average, affect the yield appreciably.

One difficulty with these estimates is that data are available for only a limited part of the yield curve; consequently, the MSY and corresponding optimum effort estimates have low precision and may be biased. The analysis is only applicable to the longline fishery as presently constituted and has no value in predicting the potential for surface fisheries.

3.5.5.2 Yield-per-recruit analysis

A theoretical analysis has been carried out on the effect of varying the age at first capture on yield under different stock-recruitment models (SAWS/BP/8). The analysis suggested that no substantial increase in Y/R to the longline fishery could be achieved by altering the size selectivity of the fishery.

TABLE 12. Number of longline vessels based at Pago Pago, American Samoa, by nationality, 1954-76 (from SAWS/BP/8)

Year	Number of vessels				
	Japan	Taiwan	Korea	Undetermined	Total
1954	17	--	--	1	18
1955	50	--	--	--	50
1956	56	--	--	--	56
1957	61	--	--	1	62
1958	76	--	2	1	79
1959	64	--	4	1	69
1960	60	--	3	1	64
1961	55	--	2	1	58
1962	79	--	5	1	85
1963	117	--	10	1	128
1964	94	11	16	--	121
1965	101	23	33	--	157
1966	79	76	55	--	210
1967	62	128	69	--	259
1968	39	110	85	--	234
1969	18	71	76	--	165
1970	9	115	81	--	205
1971	4	124	90	--	218
1972	2	135	95	--	232
1973	--	172	172	--	344
1974	--	149	171	--	320
1975	--	77	135	--	212
1976	--	93	119	--	212

3.5.5.3 Recruitment analysis

No information is available on the relationship between stock and recruitment.

3.5.5.4 Current appraisal

The conclusion of the workshop participants was that current fishing levels do not appear to be adversely affecting the stock. Further increases in longline fishing effort would result in only a slight increase in yield, if any. The impact of the development of major surface fisheries on the stock is unclear and consequently, the development of such fisheries should be closely monitored.

3.5.6 Recommendations

A number of research needs can be identified; among these are: (1) collection of catch-effort and size-frequency data from fleets that are not now being monitored; (2) collection of data on surface fisheries which might develop; (3) expanded studies using the age-specific simulation models and different hypotheses of natural mortality and catchability; (4) tagging of fish in the surface fisheries, such as in New Zealand, to determine among other things the degree of interaction of the surface and longline fisheries.

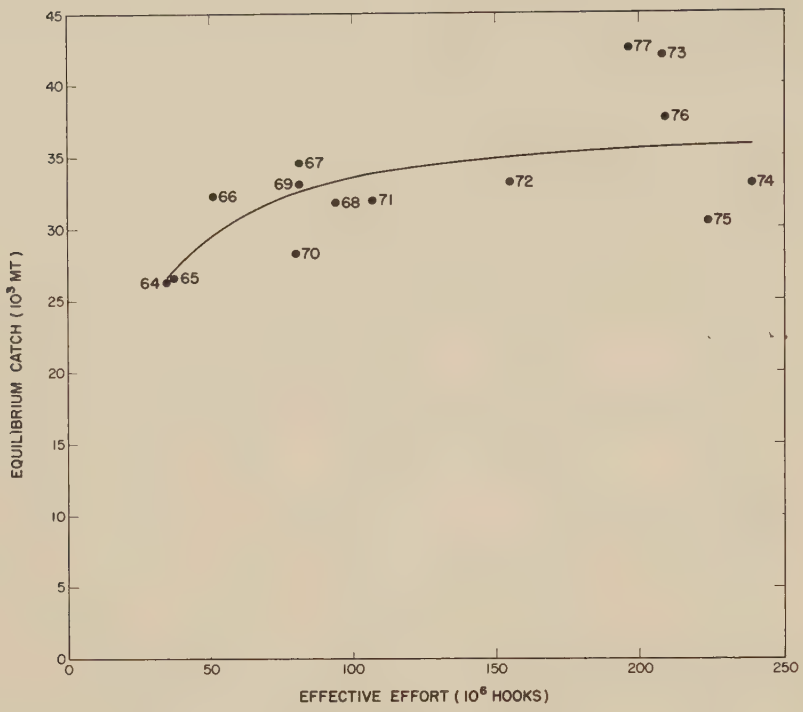


Figure 21. Projected relationship between equilibrium yield and effective effort for South Pacific albacore, based on production model with 3-yr effort averaging (from SAWS/BP/8)

3.6 Southern Bluefin Tuna (Rapporteurs: Robert A. Skillman and Chiomi Shingu)

The southern bluefin tuna, Thunnus maccoyii, is a subtropical and temperate species restricted to the Southern Hemisphere where it has a nearly circumpolar distribution (Figure 22). The two major fisheries for this species are the Australian surface fishery and the Japanese longline fishery.

3.6.1 Review of current research

Both the FSFRL and the Commonwealth Scientific and Industrial Research Organization (CSIRO) of Australia, have active research programs on this species and both collect detailed catch and size-frequency statistics. Australia has conducted an extensive tagging program that has provided information on migration, mortality coefficients (SAWS/BP/13), growth parameters (SAWS/BP/14), and stock structure. Stock assessment analyses have been made by both countries, and the results of a cohort analysis were presented at this meeting by the FSFRL (SAWS/BP/11). Results of other studies were also presented at the workshop (SAWS/BP/12, SAWS/BP/15, and SAWS/BP/24).

3.6.2 Review of fishery data

Excellent catch and size-composition data are available for both the surface and longline fisheries. Detailed fishing effort statistics are available only for the Japanese longline fishery. The available statistics are regularly exchanged between Japan and Australia. At the present time, Australia is developing a logbook system that will provide additional statistics on fishing effort and catch locality.

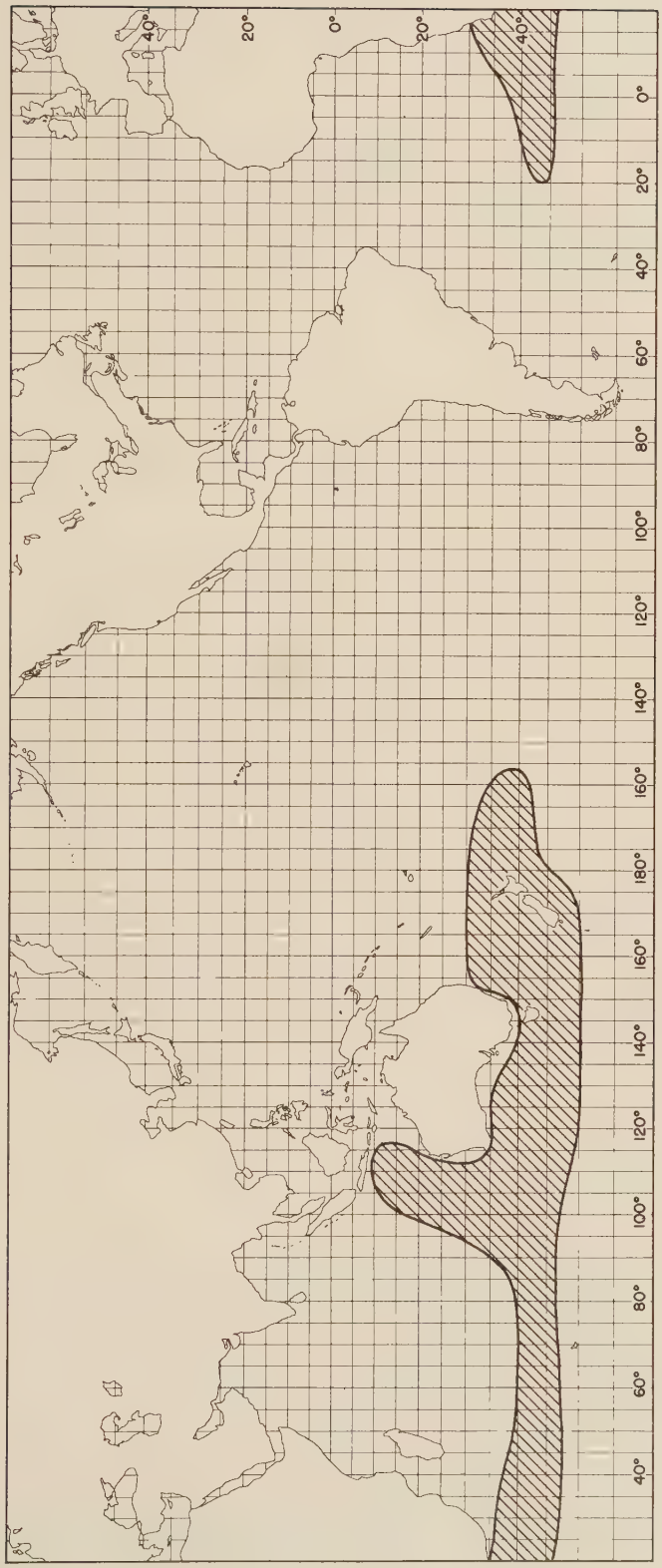


Figure 22. Distribution of southern bluefin tuna (from SAWS/BP/25)

While the catches of southern bluefin tuna by Korean and Taiwan longline vessels are probably small, data on these catches are not now being utilized and should be included in future stock assessment analyses. It was suggested that small southern bluefin tuna are being caught off Indonesia and possibly in other areas. This possibility should be investigated.

3.6.2.1 Catch trends

The numbers of southern bluefin tuna caught annually in the Japanese longline and Australian surface fisheries during the period from 1952 through 1977 are shown in Figure 23). The Japanese catch reached a peak in 1961 and decreased with some fluctuation thereafter. The Australian catch peaked in 1969, declined to below 700,000 fish in 1973 and rose again from 1974 through 1977.

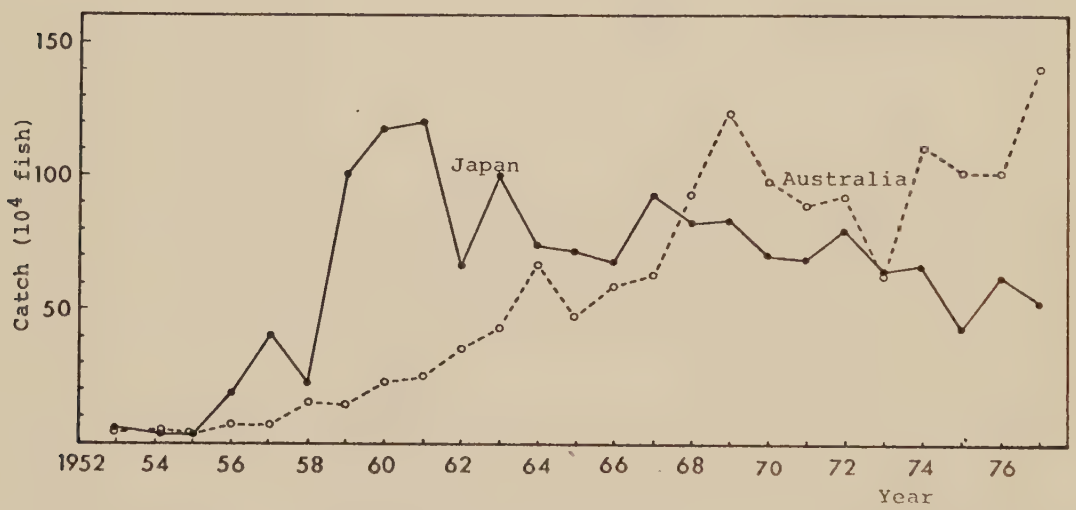


Figure 23. Annual catches of southern bluefin tuna by the Japanese and Australian fisheries (from SAWS/BP/11)

3.6.2.2 Effort trends

Data on fishing effort (Figure 24) for the Japanese longline fishery by area (Figure 25) indicate a decrease in effort during the last 10 yr in areas 1, 2, and 8. There was an increase in fishing effort only in areas 7 and 9. No trend is apparent in other areas.

As indicated above, fishing effort statistics are currently not available for the Australian surface fishery.

3.6.2.3 Trends in catch per unit effort

Japanese longline CPUE statistics for several different fishing grounds are also shown in Figure 24. In areas 1, 2, and 4, the catch rate peaked several years after the beginning of fishing and slowly declined thereafter. In areas 5, 7, and 8 the catch rate started out at a relatively high level then gradually declined. The catch rate in area 9 has shown little fluctuation and no discernible trend.

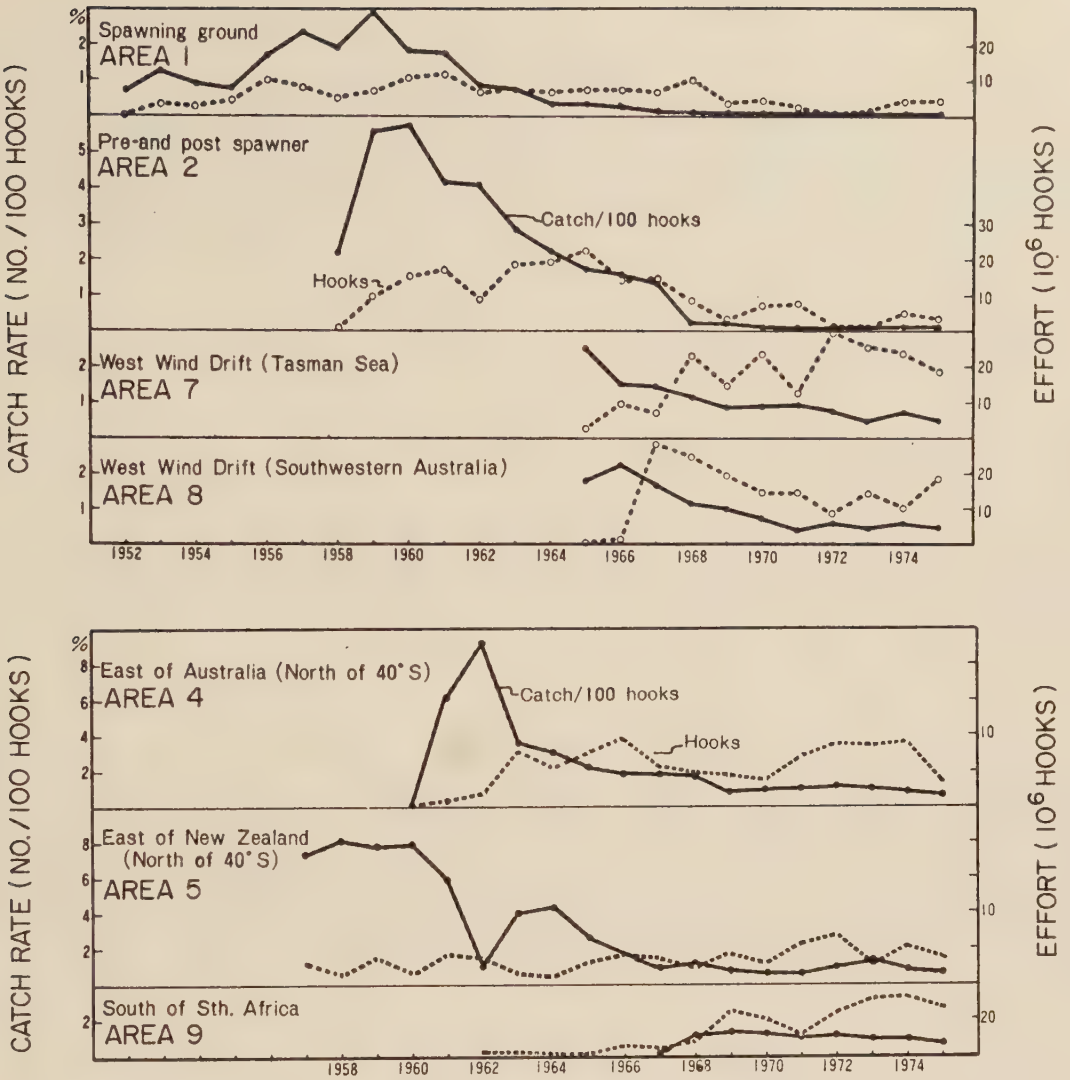


Figure 24. Annual fishing effort and catch per effort by area in the Japanese longline fishery for southern bluefin tuna (from SAWS/BP/25)

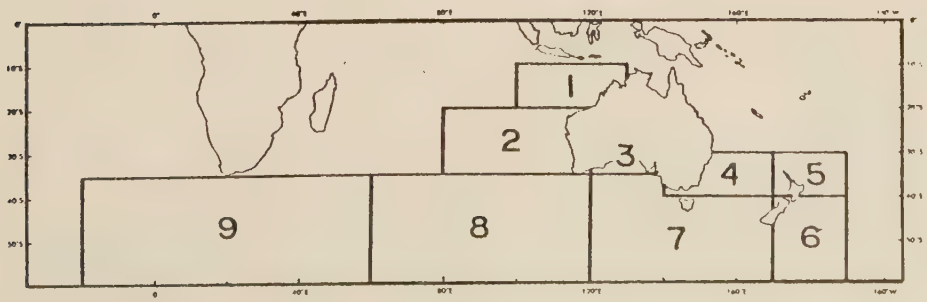


Figure 25. Fishing grounds in the Japanese longline fishery for southern bluefin tuna (from SAWS/BP/25)

3.6.3 Stock structure

It is believed that there is only one stock of southern bluefin tuna based on the following evidence: Only one spawning area is known, and this is just south of Java; fish tagged in the Australian surface fishery have been recaptured from virtually the entire range of the species (SAWS/BP/24); some small fish tagged in the Indian Ocean by Japanese workers were subsequently recaptured in the Australian surface fishery; there are small fish off Africa, but their relation to the fish occurring off Australia is not known (SAWS/BP/24).

3.6.4 Population parameters

The general problems of estimating age composition of catches from size-frequency data and subsequent inaccuracies in the estimates of parameters were discussed (see Section 3.11.2).

This problem is specifically relevant to the southern bluefin tuna cohort analysis presented. The age composition used in this analysis was based on length-frequency data and a growth model derived from modal progressions. This conflicted with age estimates based on long-term returns. It was suggested that the cohort analysis be repeated using the von Bertalanffy parameters estimated from the tagging data. This is regarded as a particularly high priority item as the cohort analysis suggested a systematic decline in recruitment.

3.6.5 Status of stocks

3.6.5.1 Production model analysis

No production model analysis was attempted; however, Figure 26 presents the basic data. The interpretation of production models used on these data is hampered by uncertainty in estimates of the age composition of the catch. The high catches in 1959-61 could have been due to fishing on previously unexploited old fish; however, as effort has increased catches have continued to decline. An attempt should be made to assess whether a reduction in longline fishing effort would result in an increased total sustained catch.

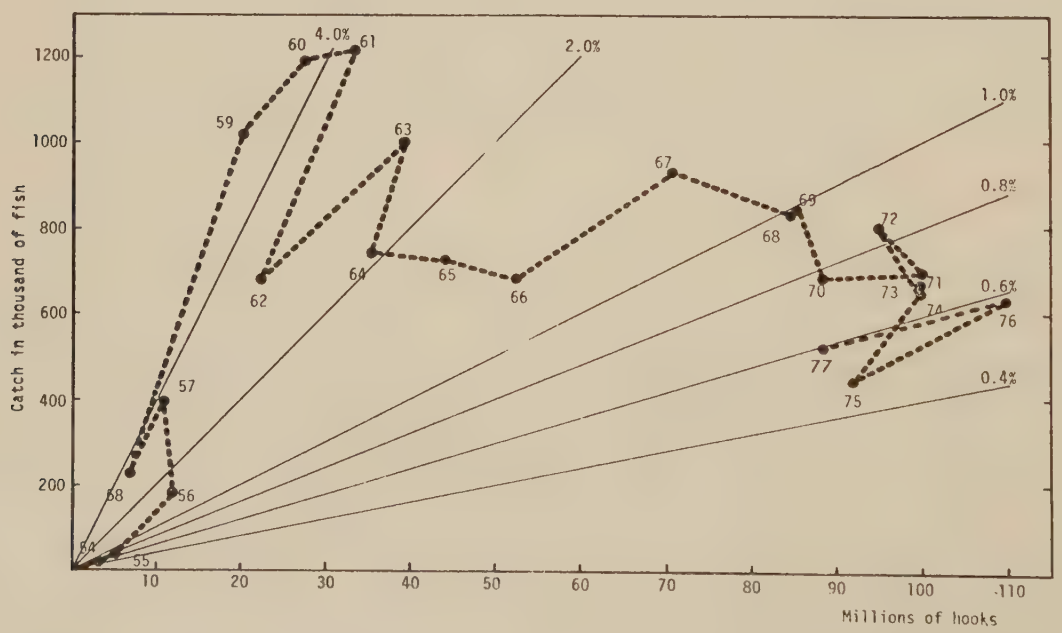


Figure 26. Relation between fishing effort and catch of southern bluefin tuna in the Japanese longline fishery. Lines show catch per 100 hooks in percentage (from SAWS/BP/11)

3.6.5.2 Yield-per-recruit analysis

Some preliminary Y/R analyses have been performed though they were not presented at the workshop. One analysis indicated that a decrease in effort in the Australian fishery would not cause an increase in Y/R. The same seemed to be true for the Japanese longline fishery. The capture of age 2 fish while not undesirable from a Y/R viewpoint may be economically unsound. An evaluation of the gross value of the catch should be made, particularly in view of the large change in value per unit weight of the fish with increasing age.

3.6.5.3 Recruitment analysis

The cohort analysis suggested that recruitment has declined from the beginning of the fishery (top of Figure 27). However, the cohort analysis was based on a particular dissection of the size-composition data which may have biased the results. This problem requires further analysis because a different estimated age-composition data may yield different conclusions concerning recruitment.

3.6.5.4 Current appraisal

From the evidence presented, it appears that increasing fishing effort for either or both fisheries would not result in substantially increased catches. If recruitment has in fact been declining then increased effort could result in a decrease in total catch.

3.6.6 Effects of regulations

There are three regulatory measures voluntarily put into effect by the major governments involved in the fishery. The Japanese longline fishermen have voluntarily closed certain areas in some seasons to longlining. This measure has prevented a further decline in the age at first capture by the longline fishery. Australia has had limited entry regulations in effect since 1976 for purse seiners and since 1977 for bait boats, though the latter are probably temporary. There has been no measurable effect of limiting bait boats, but limiting the number of purse seine vessels has probably held fishing mortality down. Finally, there is a state regulation that allows only vessels registered in Western Australia to fish within 3 miles of the coast of that state. This regulation probably has no effect on the stock.

3.6.7 Recommendations

3.6.7.1 Statistics

It was recommended that Australia continue its logbook system to improve fishing effort and catch location statistics for the surface fishery.

It was also recommended that statistics on catches made by Korean and Taiwan longline vessels be made more readily available.

3.6.7.2 Research

The possibility that juvenile southern bluefin tuna are caught in the Indonesian surface fisheries should be investigated.

The early Australian tag recovery data should be reevaluated to investigate the problems encountered in using the von Bertalanffy growth curve in the cohort analysis.

The procedures used in estimating age composition from length-frequency data should be investigated. Special attention should be given to the effects of using variable growth and mortality parameters on the distribution of ages within size classes.

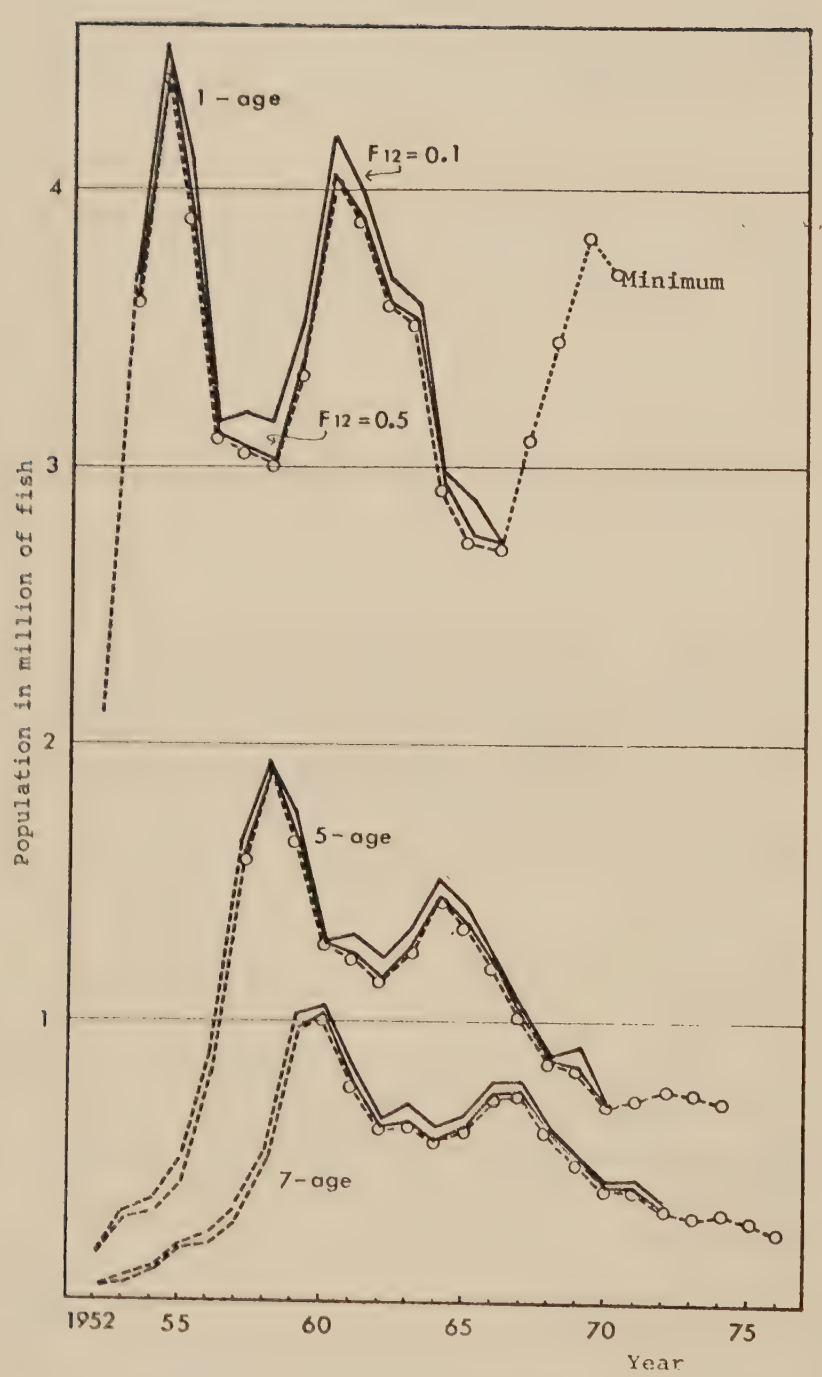


Figure 27. Estimated population (in millions of fish) at age 1, age 5, and age 7. Points of 1967-70 fishing years for age 1, 1971-74 for age 5, 1973-76 for age 7, are estimates from incomplete year class series (from SAWS/BP/11)

3.7 Indian Ocean Yellowfin Tuna (Rapporteurs: Peter M. Miyake and Ziro Suzuki)

Yellowfin tuna, Thunnus albacares, are distributed throughout the Indian Ocean between lat. 20°N and 40°S (Figure 28). Catches are made primarily by longlining and are concentrated in equatorial waters and off eastern Africa. Yellowfin tuna are also taken in localized fisheries by trolling gear, drift nets, and pole and line.

The longline fishery in the Indian Ocean began in 1952 when Japanese longliners commenced fishing for yellowfin tuna. Through the years the target species for the Japanese fleet changed from yellowfin tuna to albacore, then to bigeye tuna, and finally to southern bluefin tuna. Korean and Taiwan longliners now account for most of the longline-caught yellowfin tuna.

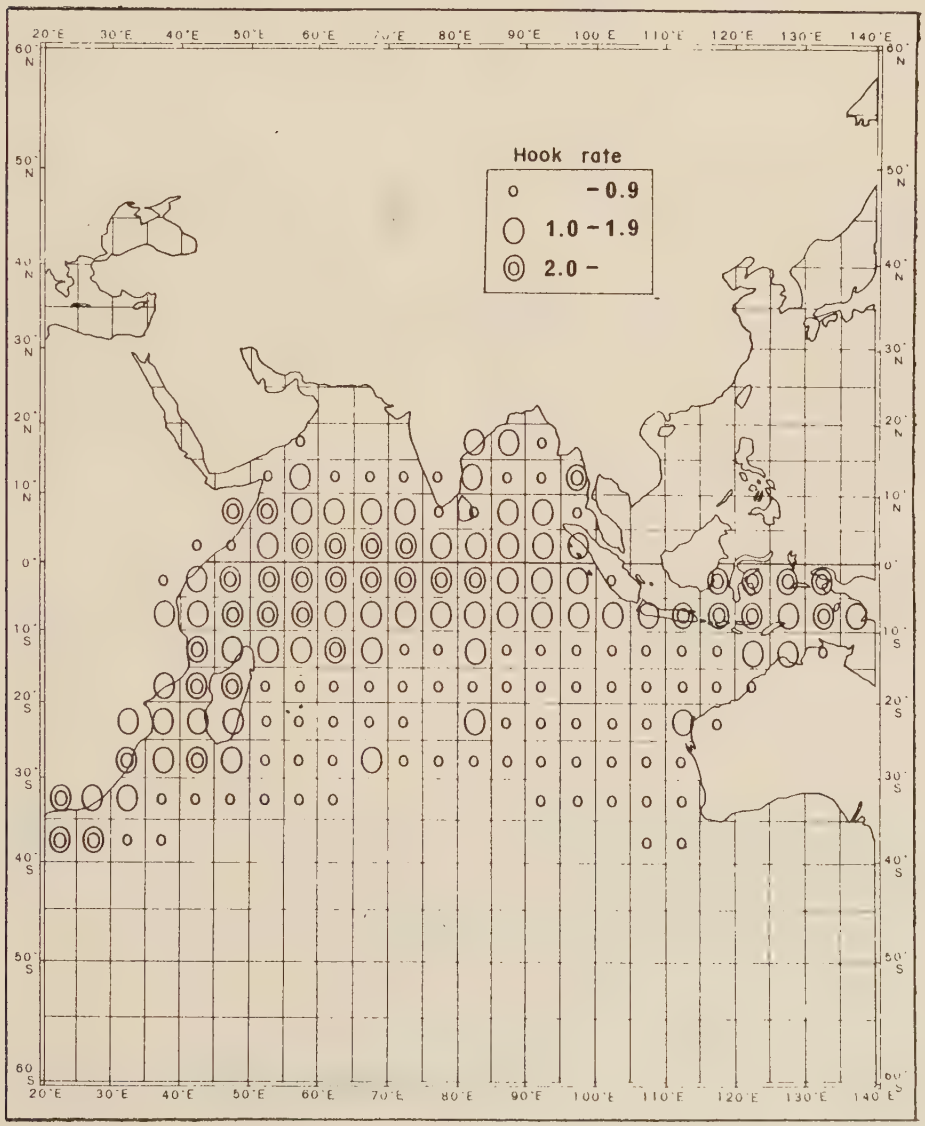


Figure 28. The distribution of yellowfin tuna in the Indian Ocean (from Morita and Koto, 1971)

3.7.1 Review of current research

Two background papers on stock assessment of yellowfin tuna in the Indian Ocean were available (SAWS/BP/17 and SAWS/BP/21).

3.7.2 Review of fishery data

3.7.2.1 Catch trends

Table 13 shows estimates of the total yellowfin tuna catches in the Indian Ocean. Some discrepancies in the important longline catch data (Japan, Korea, and Taiwan) from various sources were noted. In addition, the data for the U.S.S.R. and Sri Lanka also need close examination.

3.7.2.1.1 Longline catch

Total annual longline catches have fluctuated widely since 1954 without any definite trend. Up to and including 1968, the Japanese fleet accounted for the majority of the longline catch. As the Japanese fishery shifted from yellowfin tuna to southern bluefin tuna, the Taiwan and later the Korean fleets, accounted for increasing proportions of the longline yellowfin tuna catch.

3.7.2.1.2 Surface catch

The estimated catch by surface fisheries was considered to be less accurate than that for the longline fisheries. It was thought that the figures available for catches up to 1973 were underestimates but the statistics had been improved for recent years.

The catches for Yemen and Oman in the FAO yearbook (1977) were reported to include species other than yellowfin tuna but the exact species composition of the catch was not known. It was also noted that there had been a commercial surface fishery in Somalia several years ago which accounted for about 2,000 MT of yellowfin tuna.

The total surface yellowfin tuna catch in the Indian Ocean was estimated to be of the order of 10,000-25,000 MT. The reported catches show recent increases, but these most likely reflect an improvement in statistics.

3.7.2.1.3 Total catch

As the surface catch estimates are very unreliable and much underestimated in earlier years, any apparent trends observed in total yellowfin tuna catch are not very meaningful. Recent total catches have been in the range of 40,000 to 50,000 MT, and the highest catch, 88,000 MT, was recorded in 1968.

3.7.2.2 Effort trends

The best effort data presented were those for the Japanese longline fleet. The effective fishing effort was computed for the Japanese fleet and then extrapolated for the entire longline fishery (Figure 29) on the basis of total catches. The effective effort steadily increased up to 1968 and remained at a high level with the exception of a low observed in 1973. The effective effort computed for the postulated area of two possible stocks (Figure 30) also showed the same trends.

3.7.2.3 Trends in catch per unit effort

Catch per effective effort for the Japanese longline fleet was computed for the eastern, western Indian Ocean, and total Indian Ocean (Figure 31).

TABLE 13. Estimated annual catches (metric tons) of Indian Ocean yellowfin tuna, by nation and year (adapted from Table 3, SAWS/BP/21)

	Longline catch						Surface catch											
Year	Japan[1]	Taiwan[2]	Korea[3]	U.S.S.R.[3]	Sri Lanka[3]	Total longline	Australia[4]	Bangladesh[4]	India[4]	Madagascar[4]	Maldives[3]	Pakistan[4]	Sri Lanka[4]	Seychelles[3]	Yemen[3]	Oman[3]	Total surface	Grand total
1952	8,858					8,858												8,858
1953	13,258					13,258												13,258
1954	24,883	210				25,093												25,093
1955	46,459	689				47,148												47,148
1956	64,402	1,089				65,491												65,491
1957	36,036	1,252				37,288												37,288
1958	25,727	1,825				27,552												27,552
1959	24,428	2,380				26,808												26,808
1960	40,292	2,241				42,533												42,533
1961	34,551	2,877				37,428												37,428
1962	51,665	3,468				55,133												55,133
1963	25,888	3,402		100		29,390												29,390
1964	24,752	2,859		300	200	28,111							2,000				[5]2,000	30,111
1965	27,579	2,180		900	200	30,859		100	800		500	500	1,700				[5]3,600	34,459
1966	44,106	4,368	100	2,600	200	51,374		200	1,000		1,500	700	2,000				[5]5,400	56,774
1967	31,597	3,380	200	3,100	300	38,577		100	1,000		1,700	800	3,600				[5]6,200	44,777
1968	50,475	22,646	4,000	2,700	400	80,221		100	1,300		1,700	700	4,100				[5]7,900	88,121
1969	25,228	21,089	7,000	1,600	400	55,317		100	1,100		1,800	600	3,800				[5]7,400	62,717
1970	14,459	11,865	8,000	2,000	300	36,624			500		1,200	300	4,000				[5]6,000	42,624
1971	13,471	16,536	6,500	1,500	200	38,207	100		200		1,300	200	3,800				[5]5,600	43,807
1972	8,880	8,833	9,600	1,600	100	29,013	100		200	200	5,000	300	6,500				[5]12,300	41,313
1973	7,470	4,216	9,200	900	100	21,886	--		200	500	5,200	200	5,100	[6]100	[6]7,400		18,700	40,586
1974	7,935	3,147	11,563	--	--	[7]22,645	--		200	1,700	4,500	--	6,070	[6]150	[6]7,391		[7]20,011	42,656
1975	8,577	3,371	11,694	--	--	[7]23,642	--		--	--	4,200	--	6,611	[6]100	[6]7,391	[6]8,500	[7]26,802	50,444
1976	3,507	2,545	12,848	--	--	[7]18,900	--		--	--	4,800	--	6,915	[6]50	[6]7,391	[6]8,280	[7]27,436	46,336
1977	3,521	6,690	31,838	--	--	[7]42,049	--		--	--	4,300	--	5,720	--	--	--	[7]10,020	52,069
1978	--	2,114	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--

[1]Courtesy of S. Ueyanagi, Far Seas Fisheries Research Laboratory, Japan.

[2]Courtesy of R. T. Yang, National Taiwan University, Taiwan.

[3]FAO (1977).

[4]FAO (1974, 1975).

[5]Due to the shortage of data for various fisheries, these data would be very much underestimated.

[6]May include other species.

[7]Incomplete.

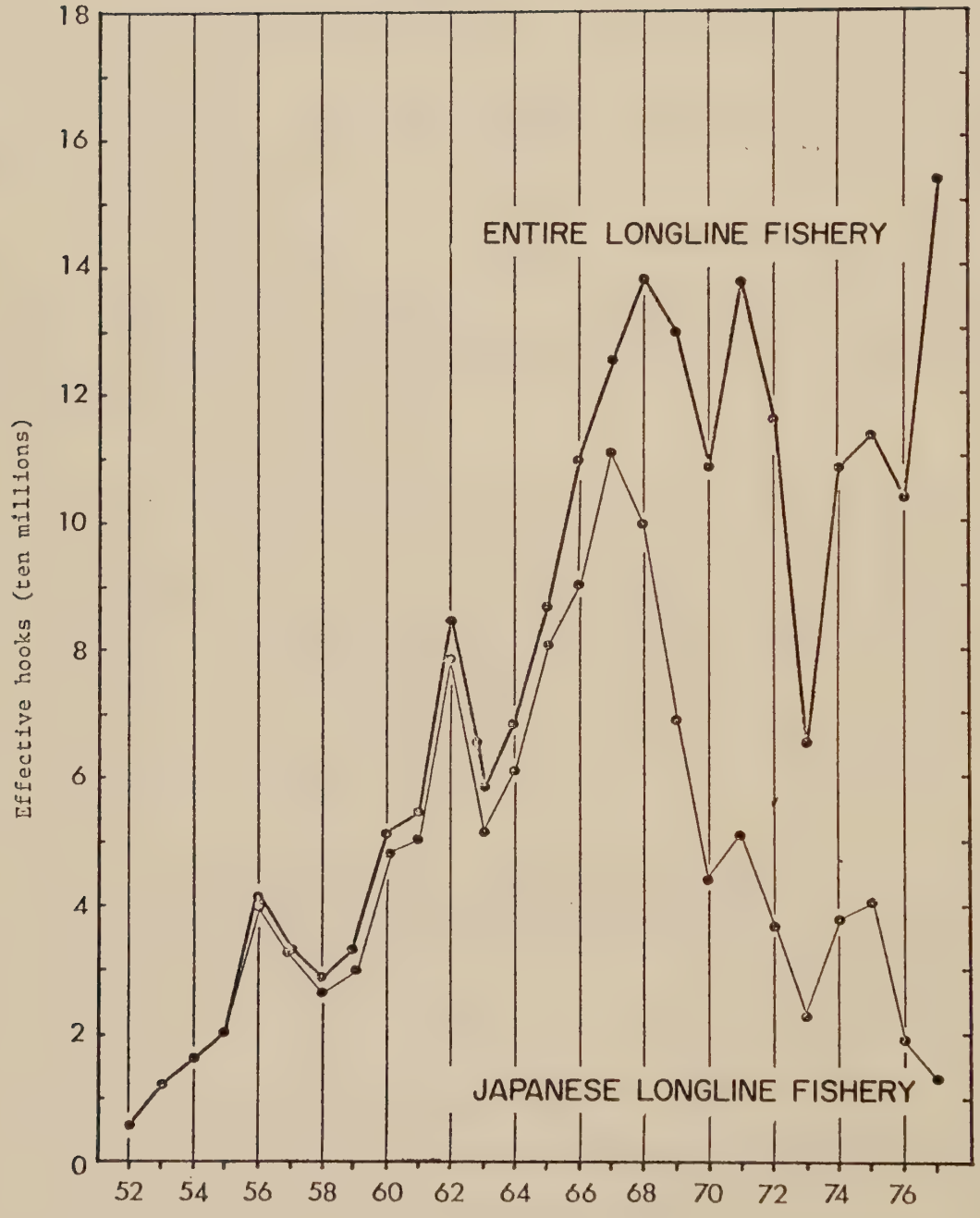


Figure 29. Annual changes in effective fishing effort for Indian Ocean yellowfin tuna by the Japanese and the entire longline fishery (from SAWS/BP/17)

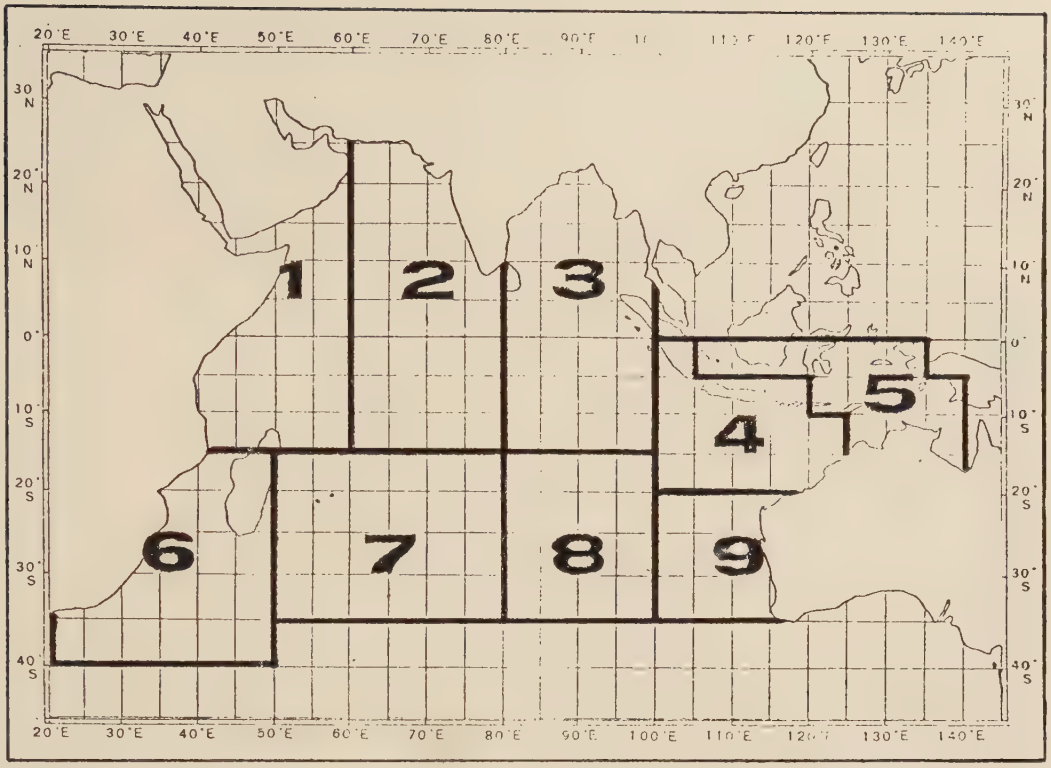


Figure 30. Division of the Indian Ocean for the compilation of length composition of yellowfin tuna taken by the Japanese longline boats. Areas 1-3 and 6-8 combined correspond to the extent of the western stock and areas 4, 5, and 9 together to that of the eastern stock (from SAWS/BP/17)

There was a generally declining trend in CPUE in the eastern Indian Ocean until the mid-1960's; thereafter the CPUE stabilized. The CPUE dropped more sharply in the western Indian Ocean than in the east. However, after the mid-1960's it stabilized at about the same low level as for the eastern stock. Average catch rates in the entire Indian Ocean in recent years decreased to 30% of those in the early years of the fishery.

3.7.3 Stock structure

The past analyses of biological data (Morita and Koto, 1971; Huang et al., 1973) and spatial-temporal distribution of longline catches suggested that there are at least two yellowfin tuna stocks in the Indian Ocean, with the dividing line at long. 100°E. The catch rate analyses and the estimates of stock density by age were made under the two-stock hypothesis. However, the production model analysis had to be carried out under the one-stock hypothesis due to the lack of adequate catch and biological data.

Since the biological and catch data indicated that the yellowfin tuna stocks in the Banda Sea are part of the eastern Indian Ocean stock, the Banda Sea catch is included in the Indian Ocean catch, whereas the FAO statistics place the Banda Sea in the Pacific.

3.7.4 Population parameters

Data are available on length-weight (Morita, 1973) and growth parameters (Huang et al., 1973) of Indian Ocean yellowfin tuna. Estimates have also been made of the natural mortality coefficient and catchability coefficient based on Japanese data (SAWS/BP/17).

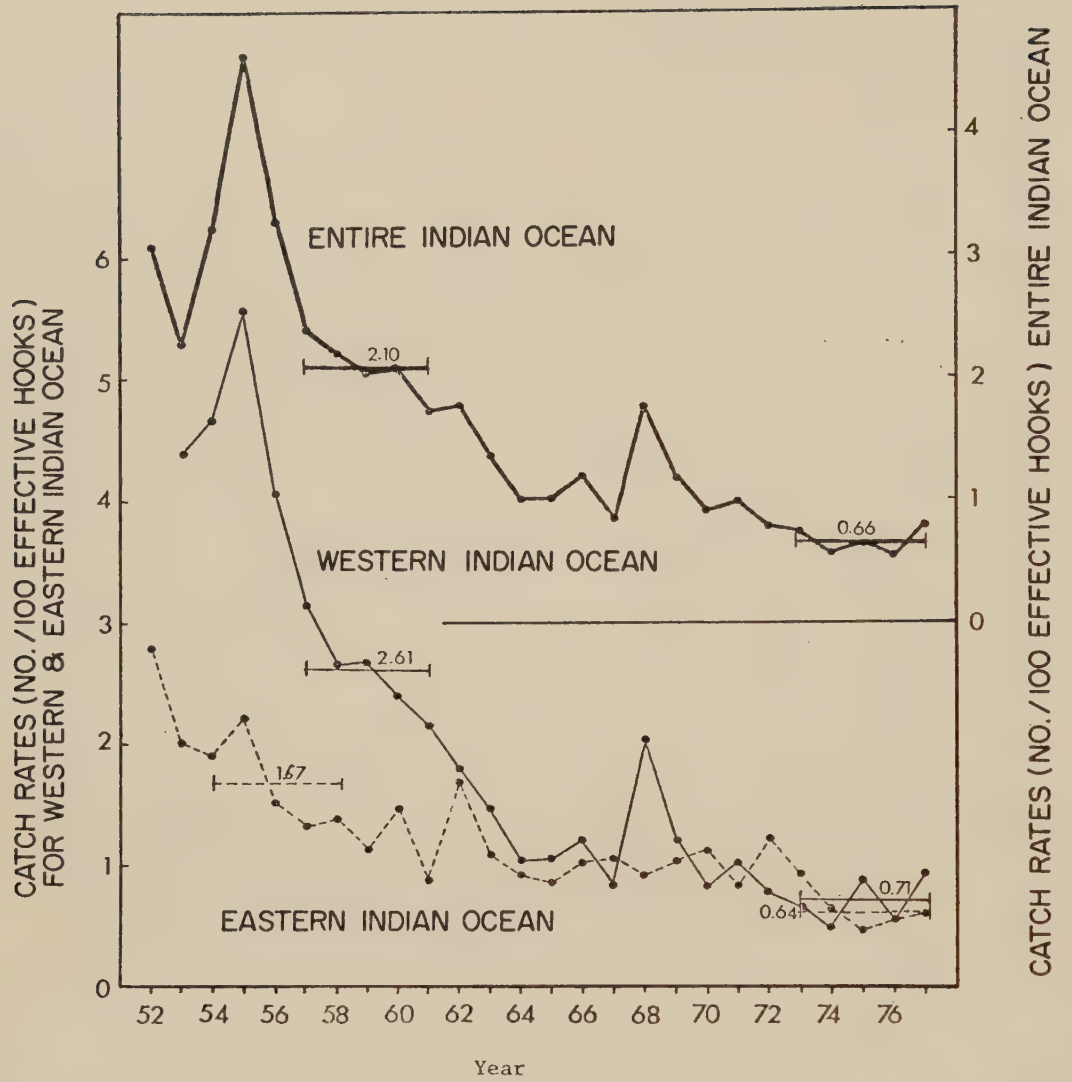


Figure 31. Yellowfin tuna catch rates in the Japanese longline fishery in the Indian Ocean. Numerals in the figure denote the average hook rates during the 5 yr shown by bars (from SAWS/BP/17)

The group recognized that these estimates needed careful scrutiny as a fixed age-length key had been used in the analyses. This problem was common to several species and is further discussed in Section 3.11.

3.7.5 Status of stocks

3.7.5.1 Production model analysis

The generalized production model was applied to the data on total longline catch and effective effort (Figure 32). The results of another analysis based on the total yellowfin tuna catch (surface and longline) and effective effort calculated from abundance indices were in basic agreement.

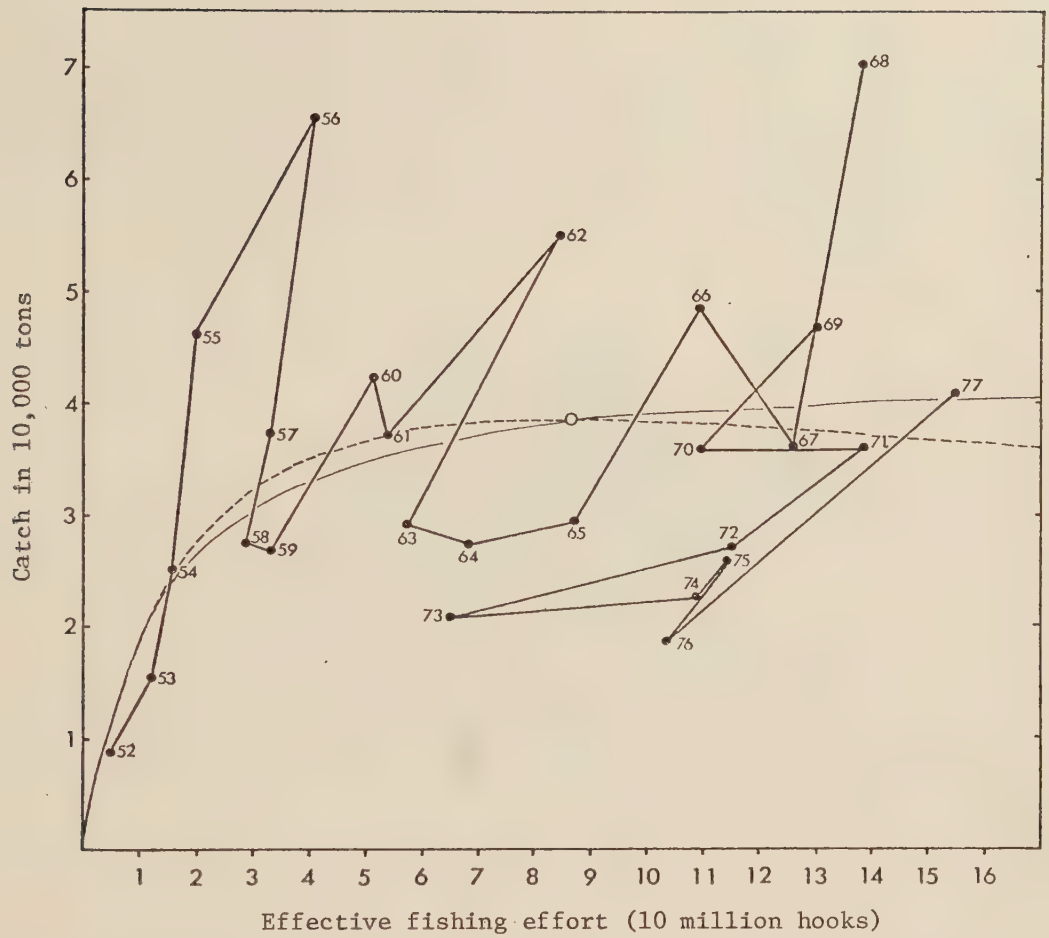


Figure 32. Relationship between observed effective longline fishing effort and catches of Indian Ocean yellowfin tuna. Two equilibrium curves have been fitted. Dotted curve (k = 4, m = 0.28 with optimum fishing effort shown by an open circle), solid curve (k = 4, m = 0.0) (from SAWS/BP/17)

Because the total catch estimates are rather inaccurate, it is premature to pinpoint an MSY for Indian Ocean yellowfin tuna, except to indicate that the MSY is thought to be between 40,000 and 60,000 MT. The nature of the yield curve suggested that a drop in longline effort is unlikely to result in a substantial drop in total catch.

3.7.5.2 Yield-per-recruit analysis

Sufficient basic data are not available for Y/R analysis.

3.7.5.3 Recruitment analysis

Stock size indices by age had been calculated under the one- and two-stock hypotheses (SAWS/BP/17). No relationship between stock and recruitment was evident.

3.7.5.4 Current appraisal

It is unlikely that longline catches of Indian Ocean yellowfin tuna could be increased appreciably above the 1977 level of 42,000 MT. However, the group felt that there was a potential for increased landings of yellowfin tuna by surface fisheries. While increased surface fishery might reduce the abundance of yellowfin tuna available to longliners, the total catch of yellowfin tuna and the total Y/R would probably increase.

3.7.6 Recommendations

3.7.6.1 Statistics

More accurate estimates of catch, effort, and size composition are needed, particularly for the surface fisheries.

Catch, effort, and size-frequency data by temporal-spatial strata are essential for analyses of subpopulations and for detailed Y/R studies. Since analysis to date have been based only on data from the Japanese longline fleet which has largely withdrawn from the areas of high yellowfin tuna concentration in the Indian Ocean, data from the Taiwan and Korean longline fisheries which still target on yellowfin tuna should be made available and analyzed.

3.7.6.2 Research

Since an adequate data base for reliable stock assessment will not be available for some time, it is important to evaluate the limitations of current appraisals based on incomplete data. The sensitivity of these appraisals to assumptions on stock structure and other considerations should be examined.

Mortality coefficient estimates should be studied further, especially in relation to fishing effort.

Changes in longline catchability coefficients should be carefully studied in relation to the total intensity of fishing effort exerted, and in relation to changes in gear characteristics.

Simulation studies should be undertaken to evaluate the potential impacts of various fishery developments, particularly expansion of the surface fisheries.

3.8 Indian Ocean Bigeye Tuna (Rapporteurs: Robert A. Kearney and Susumu Kume)

Bigeye tuna, Thunnus obesus, are distributed throughout the Indian Ocean between lat. 20°N and 40°S (Figure 33). They are taken primarily by longliners from Japan, Korea, and Taiwan. Longline catch records indicate that bigeye tuna are concentrated in the equatorial area, including the Banda Sea, throughout the year and along lat. 30°S during the southern winter.

3.8.1 Review of current research

The only current research on Indian Ocean bigeye tuna is that by Japanese scientists. Two background papers on the biology of Indian Ocean bigeye tuna were available (SAWS/BP/18 and SAWS/BP/21).

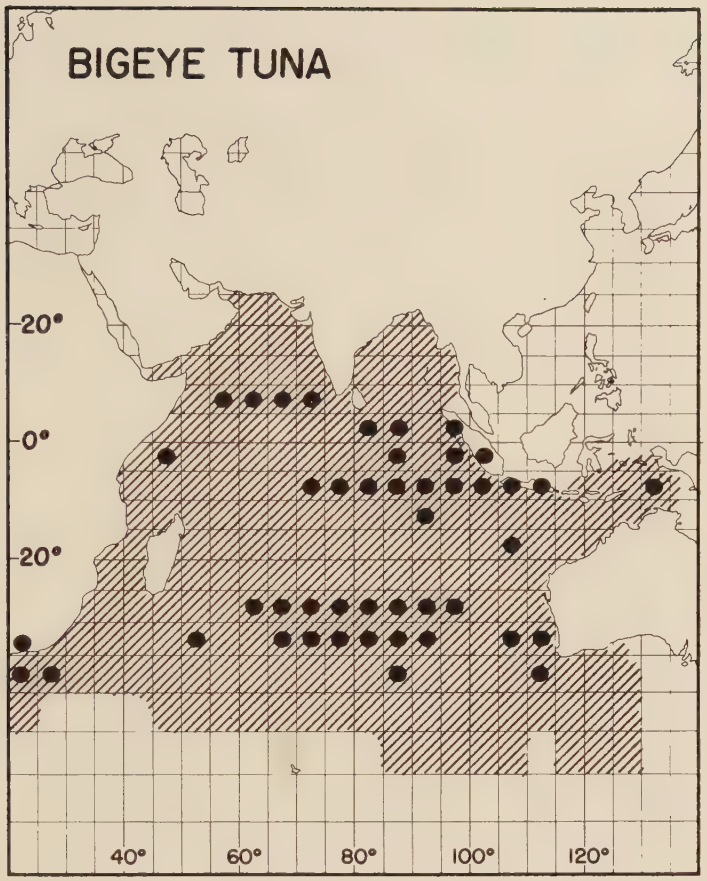


Figure 33. Distribution of bigeye tuna in the Indian Ocean. • = area of relatively high abundance (area in which the average catch rate was >1.1/100 hooks during any quarter) (adapted from Figure 5, SAWS/BP/18)

3.8.2 Review of fishery data

3.8.2.1 Catch trends

Catches of bigeye tuna in the Indian Ocean by country are summarized in Table 14. The total catch increased steadily from 1952 until 1968 after which there was a temporary decline. In recent years the total catch has again improved and landings are well above previous levels.

The most striking feature of the recorded catches of Indian Ocean bigeye tuna in recent years has been the replacement of Japan by Korea as the major fishing nation. In 1966, which was the first year Korea participated in this fishery, Japan took 91% of the longline catch and Korea 0.4%. By 1977 Japan's share had fallen to 14% and Korea's increased to 67%; the Taiwan catch remained at about the same level during this period.

TABLE 14. Annual catch of bigeye tuna by countries in the Indian Ocean (including the Banda Sea) (from SAWS/BP/18)

Year	Japan	Taiwan	Korea	Yemen	Total
			(Thousand metric tons)		
1952	1.5				1.5
1953	3.6				3.6
1954	7.9	0.1			8.0
1955	10.1	0.2			10.3
1956	13.4	0.6			14.0
1957	12.4	0.9			13.3
1958	11.3	1.5			12.8
1959	8.9	1.5			10.4
1960	15.7	1.3			17.0
1961	13.6	1.9			15.5
1962	18.7	1.2			19.9
1963	12.4	1.7			14.1
1964	16.8	1.8			18.6
1965	18.2	1.4			19.6
1966	22.6	2.2	0.1		24.9
1967	22.3	2.3	0.2		24.8
1968	24.6	7.2	5.4		37.2
1969	15.0	8.0	3.1		26.1
1970	13.6	7.6	1.7		22.9
1971	11.8	5.7	4.1		21.6
1972	8.8	4.1	4.3		17.2
1973	5.7	3.0	5.6		14.3
1974	7.7	4.4	13.4	1.2	26.7
1975	8.5	4.0	24.7	1.5	38.7
1976	2.9	3.2	21.0	1.7	28.8
1977	5.2	5.2	24.6	1.8	36.8

3.8.2.2 Effort trends

Unfortunately the data on total fishing effort on bigeye tuna are not as good as those for total catch. In the early years of the longline fishery in the Indian Ocean the fishing effort was dominated by Japan and good statistics were available. However, in recent years Japanese effort has been substantially replaced by that from Korea and Taiwan for which very little effort data are available. Estimates of total longline fishing effort based on the known Japanese effort and a comparison of Japanese catch with total catch have been presented in Table 15.

3.8.2.3 Trends in catch per unit effort

The catch rate for Indian Ocean bigeye tuna decreased slowly from about 0.7 fish/100 hooks in 1957 to about 0.4 fish/100 hooks in 1976 before increasing suddenly to over 0.9 fish/100 hooks in 1977 (Figure 34). It was noted that while there obviously was an appreciable increase in the CPUE in 1977, the reported increase may be exaggerated for the following reasons: (1) The catch rate obtained was based on Japanese data; however, by 1977 the Japanese effort accounted for only 14% of the total catch of bigeye tuna in the Indian Ocean. (2) Because the Japanese effort was certainly not uniformly distributed over the fishing area in 1977, it is possible that the CPUE figure is not representative.

TABLE 15. Catch and effort statistics for bigeye tuna in the Indian Ocean, as input data for a production model analysis, 1957-77 (from SAWS/BP/18)

Year	Japanese fleet		Total catch	Estimated total effort
	Effort (1,000 hooks)	Catch (tons)		
1957	31,390	12,412	13,270	33,560
1958	23,869	11,295	12,814	27,079
1959	26,656	8,947	10,451	31,137
1960	46,262	15,652	16,962	50,134
1961	43,276	13,554	15,458	49,355
1962	63,330	18,715	19,941	67,479
1963	41,813	12,385	14,038	47,394
1964	56,620	16,751	18,522	62,606
1965	72,152	18,208	19,750	77,549
1966	80,600	22,629	24,860	88,546
1967	97,946	22,338	24,819	108,824
1968	81,737	24,623	37,213	123,530
1969	66,789	15,009	26,059	115,961
1970	54,917	13,602	22,906	92,481
1971	56,444	11,773	21,574	103,434
1972	41,153	8,802	17,245	80,628
1973	25,428	5,744	14,299	63,300
1974	41,610	7,693	26,738	144,621
1975[1]	41,013	8,469	38,625	187,050
1976[1]	16,107	2,935	28,758	157,821
1977[1]	13,019	5,220	36,775	91,719

[1]The estimated percentage of deep longline gear used is given below:

Year	Banda Sea	Indian Ocean (except Banda Sea)
1975	20%	--
1976	20%	--
1977	50%	25%

Since the Japanese effort now accounts for such a small percentage of the total, the need to obtain improved statistics from the remainder of the fleet must be stressed.

A further analysis of the overall change in CPUE which occurred in 1977 is obviously warranted.

3.8.3 Stock structure

There are no data which suggest the occurrence of more than one stock of bigeye tuna across the Indian Ocean. However, there is evidence that the catch rates and size composition of the catches from the Banda Sea are different from those in the Indian Ocean proper. The available data were inadequate to enable an in-depth study at this time but further investigation of this phenomenon is warranted.

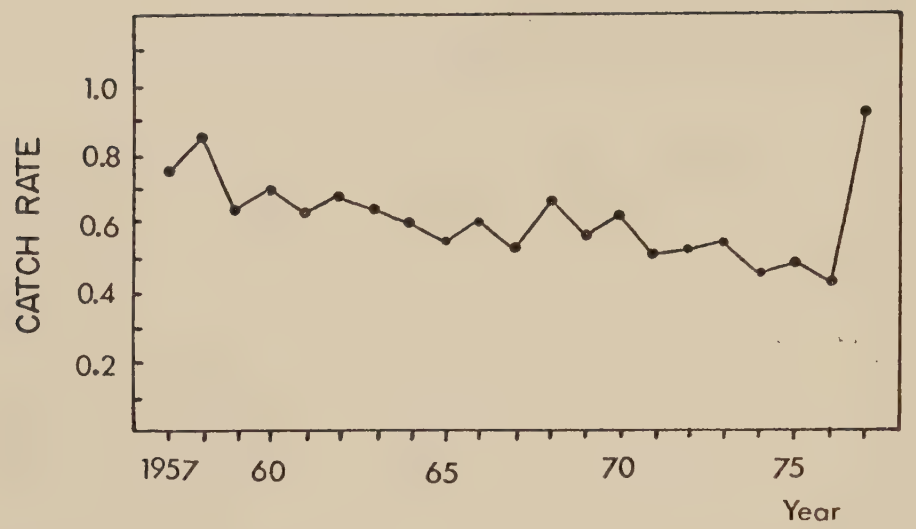


Figure 34. Annual change in overall catch rate for bigeye tuna (number/100 hooks) in the Indian Ocean, estimated from Japanese data, 1957-77 (from SAWS/BP/18)

3.8.4 Population parameters

None available for bigeye tuna in the Indian Ocean.

3.8.5 Status of stocks

3.8.5.1 Production model analysis

The relation between total catch of bigeye tuna and total effort from 1957 to 1977 was almost linear and the production model analysis (Figure 35) did not really provide any reliable prediction of MSY. In general the stock appears to be only lightly exploited. It is not possible to predict with any confidence what will happen if more effort is applied although total catch could be expected to increase and CPUE to decline.

3.8.5.2 Yield-per-recruit analysis

No information available.

3.8.5.3 Recruitment analysis

No analyses were possible.

3.8.5.4 Current appraisal

It appears that further increases in the longline fishing effort could still increase the total catch but will probably result in a gradual decrease in catch rate. It is impossible to assess what potential exists for surface fisheries on this species.

3.8.6 Effects of regulations

There are no regulations on bigeye tuna in the Indian Ocean.

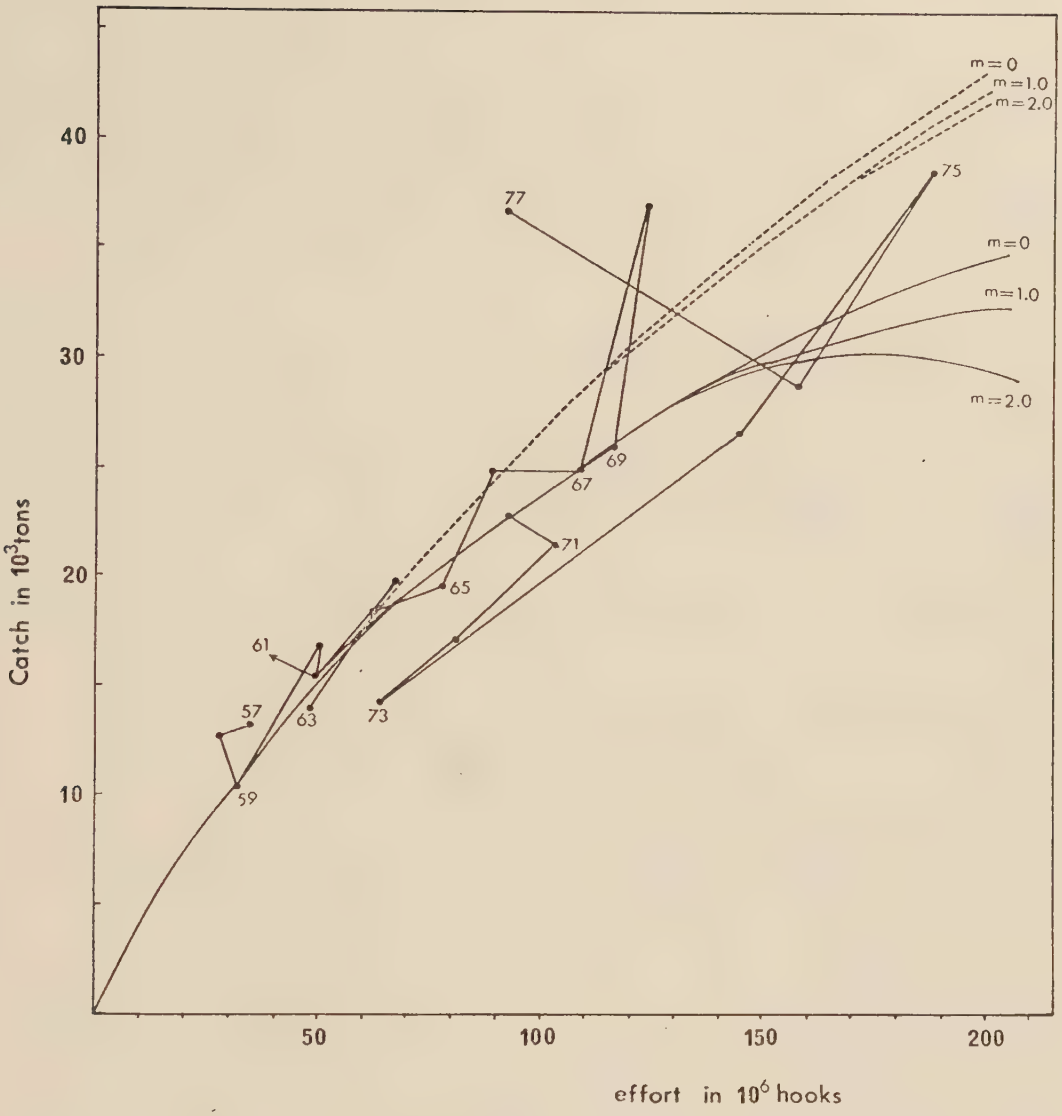


Figure 35. Sustainable average yield curves from production model analyses and observed catches for 1957-77 for the bigeye tuna in the Indian Ocean. Dotted lines were obtained from input data for 1975-77 (Case 1) and solid lines for 1957-76 (Case 2) (from SAWS/BP/18)

3.8.7 Recommendations

3.8.7.1 Statistics

Total longline catch figures for this species are good but there is an urgent need to improve the catch and effort statistics by area. This has become particularly pressing because the Japanese fishery, for which good statistics are available, is no longer representative of the fishery as a whole. In addition to Japanese data, longline catch and effort data for bigeye tuna are needed from other nations fishing in the Indian Ocean. The magnitude of surface catches should also be investigated.

3.8.7.2 Research

Research on population parameters should be encouraged but this type of research is unlikely to become a priority item in the immediate future.

The possibility that the bigeye tuna stock in the Banda Sea is different from the stock in the Indian Ocean should be investigated.

3.9 Indian Ocean Albacore (Rapporteurs: Garth I. Murphy and Rong-Tszong Yang)

Albacore, Thunnus alalunga, are distributed across the Indian Ocean between about lat. 20°N and 40°S (Figure 36). However, they appear to be more abundant south of the equator and most abundant between about lat. 15° and 35°S in the western Indian Ocean. Albacore are taken primarily by longline gear in the Indian Ocean.

3.9.1 Review of current research

Aside from routine collection of catch statistics, there is essentially no current research effort on Indian Ocean albacore.

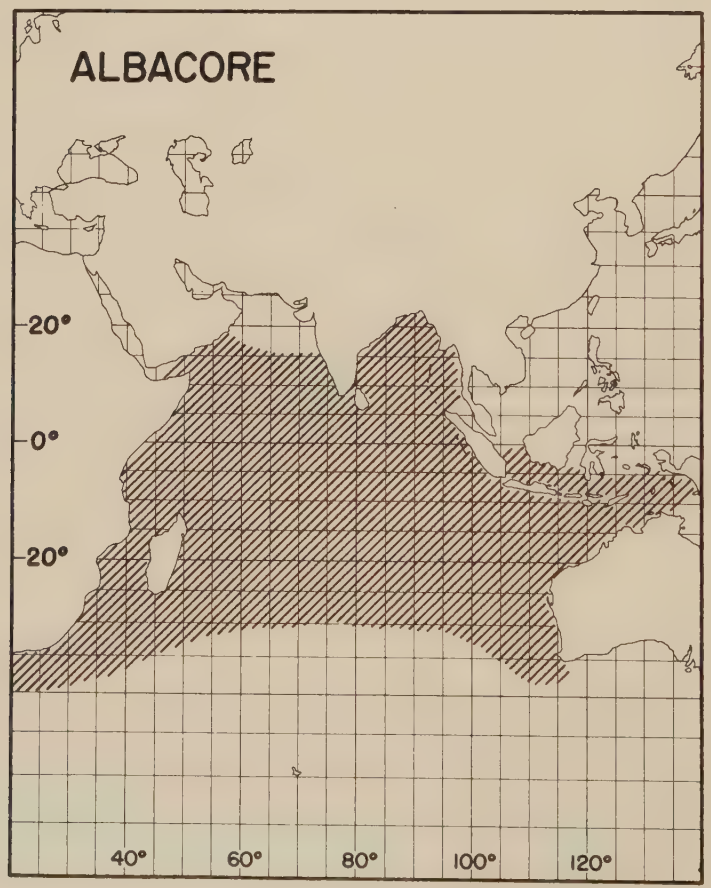


Figure 36. Distribution of albacore in the Indian Ocean (adapted from Koto, 1969)

3.9.2 Review of fishery data

3.9.2.1 Catch trends

The estimated annual catch of albacore in the Indian Ocean climbed rapidly from 67 MT in 1952 to 17,668 MT in 1962 and fluctuated widely from 1963 to 1976, reaching a high of 28,250 MT in 1974 (Table 16 and Figure 37).

3.9.2.2 Effort trends

Effective effort rose from 0.32×10^6 hooks in 1952 to 616×10^6 hooks in 1969 (Table 16 and Figure 37). Since then it has fluctuated between the 1969 level and 225×10^6 hooks.

3.9.2.3 Trends in catch per unit effort

Catch per unit of effort rose over the 1952-55 period, apparently as a result of the expansion of the fishery into new areas, and fell after 1956 (Figure 37). The decline may have been due in part to a shift in fishing grounds by the Japanese longline fleet in search of other species.

TABLE 16. Estimated total catch (metric tons), relative abundance (kg/100 hooks), and effective effort (10^6 hooks) for Indian Ocean albacore (from SAWS/BP/21)

Year	Catch (MT)	Abundance index (kg/100 hooks)	Effective effort (10^6 hooks)
1952	67	21.24	0.32
1953	1,099	33.56	3.30
1954	2,759	42.52	6.51
1955	3,302	63.84	5.19
1956	4,821	37.46	12.92
1957	4,664	42.36	11.05
1958	6,285	26.29	24.00
1959	10,412	18.63	56.09
1960	11,066	14.78	75.16
1961	15,438	16.48	94.04
1962	17,668	11.60	152.90
1963	12,620	7.37	171.88
1964	18,084	9.56	189.88
1965	12,397	7.11	167.87
1966	17,276	6.26	261.05
1967	23,703	5.74	388.46
1968	17,369	4.55	369.70
1969	21,873	3.42	615.82
1970	15,220	2.90	488.50
1971	10,186	2.02	475.34
1972	11,735	2.46	453.96
1973	22,305	9.23	232.66
1974	28,250	4.44	615.72
1975	11,205	4.55	225.16
1976	14,937	3.87	361.52

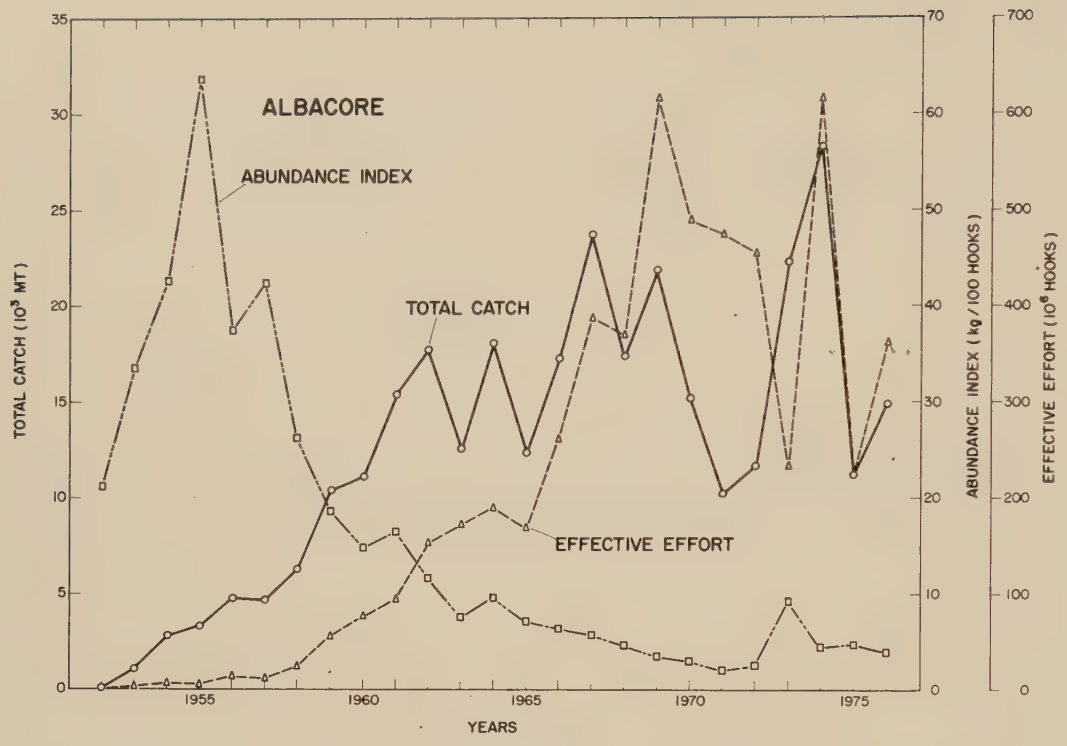


Figure 37. Estimated total catch (10^3 MT), relative abundance (kg/100 hooks), and effective effort (10^6 hooks) for Indian Ocean albacore (from SAWS/BP/21)

3.9.3 Stock structure

The limited evidence suggests that there is only one stock of albacore in the Indian Ocean, although there is possibly some exchange with albacore in the South Atlantic.

3.9.4 Population parameters

No estimates were available.

3.9.5 Status of stocks

Effort data are available only from the Japanese longline operations. However, owing to a shift in the target species, Japan's last substantial catch of albacore was in 1970.

A production model analysis based on Japanese CPUE data suggests an MSY of between 15,000 and 20,000 MT, which is the level of catches over the past decade (Figure 38). The yield curve appears to be asymptotic, with little change in catch even though effort doubled from 1966 to 1974. Together with the increase in effort has been a decrease in the average size of albacore caught. This decrease in size is thought to be attributable to a shift in the fishing grounds rather than a direct response to fishing pressure.

There appears to be no reason for concern over the future of the stocks.

3.9.6 Effects of regulations

There have been no regulations.

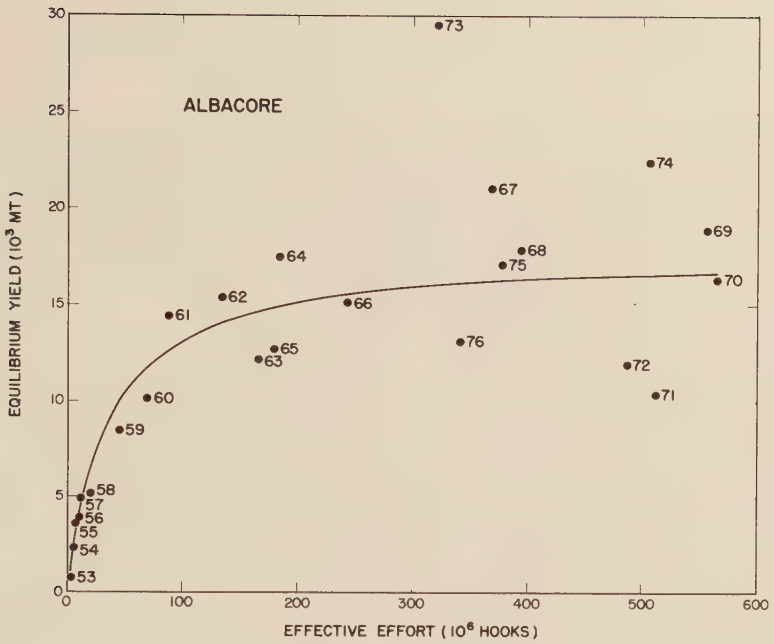


Figure 38. Predicted relationship between equilibrium yield (10^3 MT) and effective effort (10^6 hooks) for Indian Ocean albacore, based on production model analysis (from SAWS/BP/21)

3.9.7 Recommendations

Catch, effort, and size-frequency data from longline fleets of Korea and Taiwan are needed. This is particularly important because of the decrease in the significance of the Japanese fishing effort. The workshop recommended that efforts be made to improve logbook programs.

Efforts should be made to obtain and publish historical catch and effort data thought to exist in government and industry files.

3.10 Indian Ocean Billfishes (Rapporteurs: Jerry A. Wetherall and Shoji Kikawa)

Billfishes (blue marlin, Makaira nigricans, striped marlin, Tetrapturus audax, black marlin, M. indica, swordfish, Xiphias gladius, sailfish, Istiophorus platypterus, and shortbill spearfish, T. angustirostris) are widely distributed and have overlapping distributions in the Indian Ocean (Figure 39). Tunas are the target species of longliners in the Indian Ocean and billfishes are caught incidentally.

3.10.1 Review of current research

Research on billfishes in the Indian Ocean has been considered of low priority compared to the study of other species and there are few papers on the subject in the literature. The most recent is a study of the distribution and biology of striped marlin taken by Japanese longline vessels in the Indian Ocean (SAWS/BP/19).

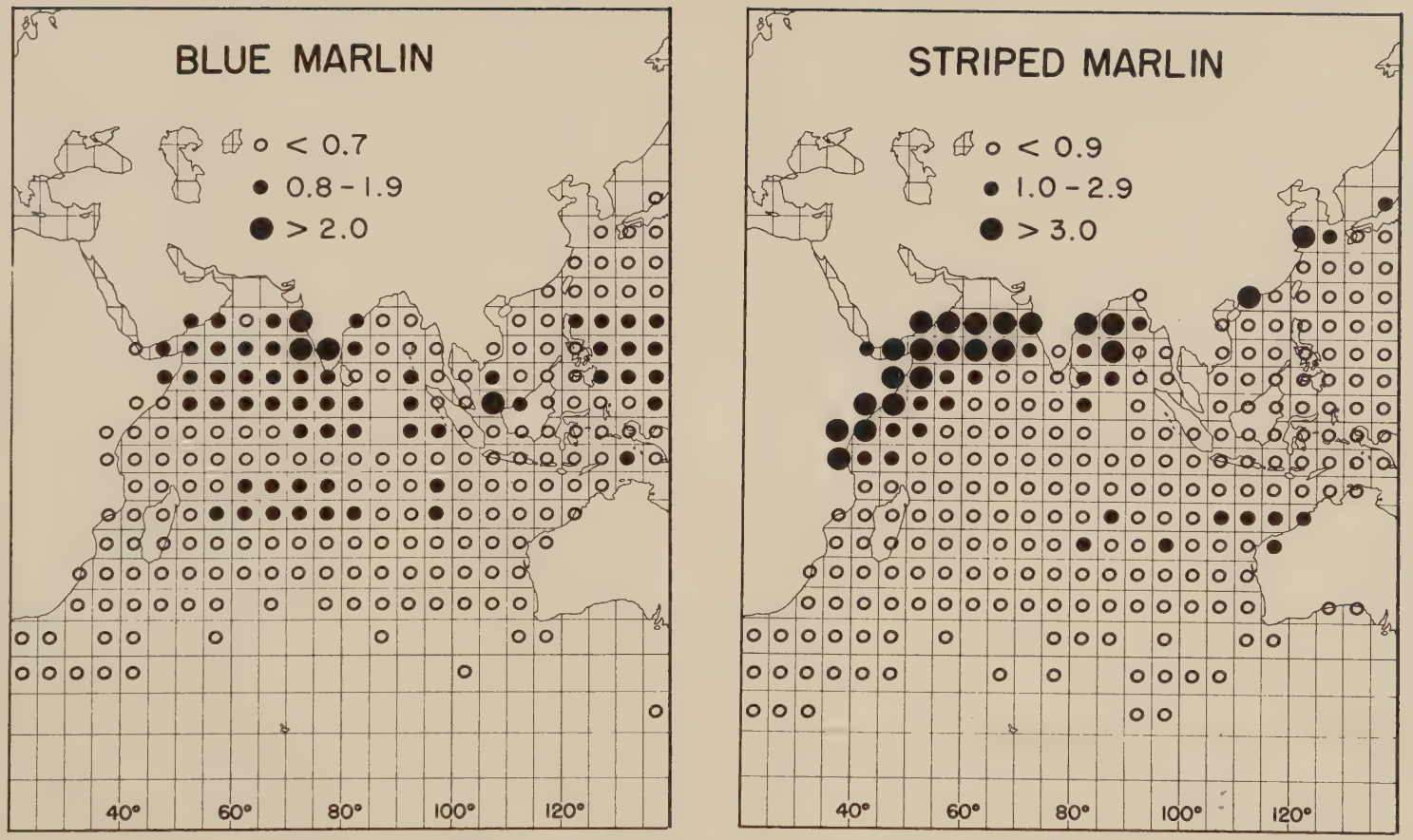
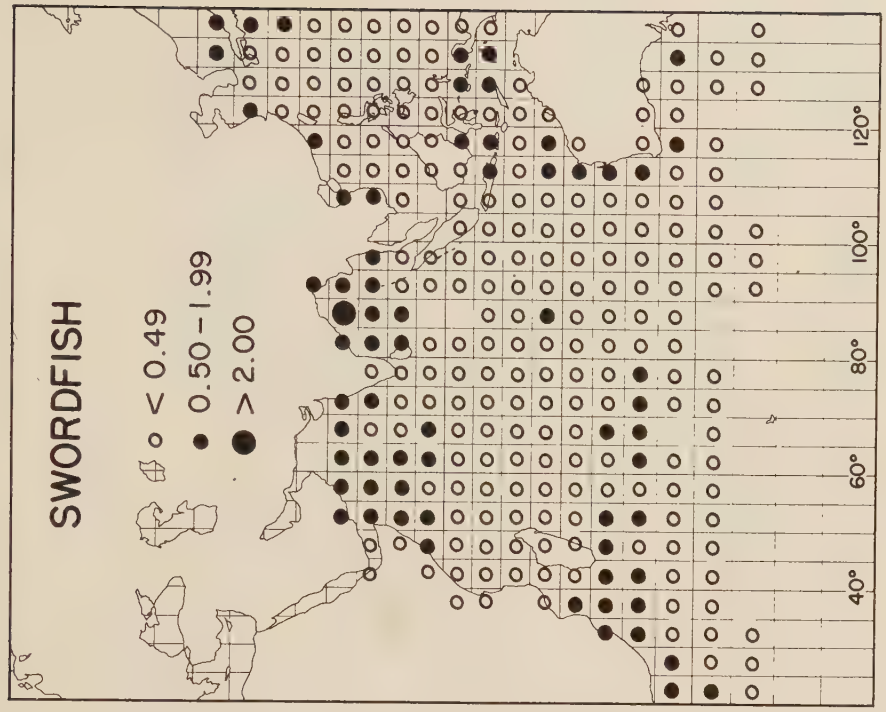


Figure 39. Distribution of billfishes in the Indian Ocean (adapted from Shomura, 1980). Circles indicate mean catch rates (number of fish/1,000 hooks)



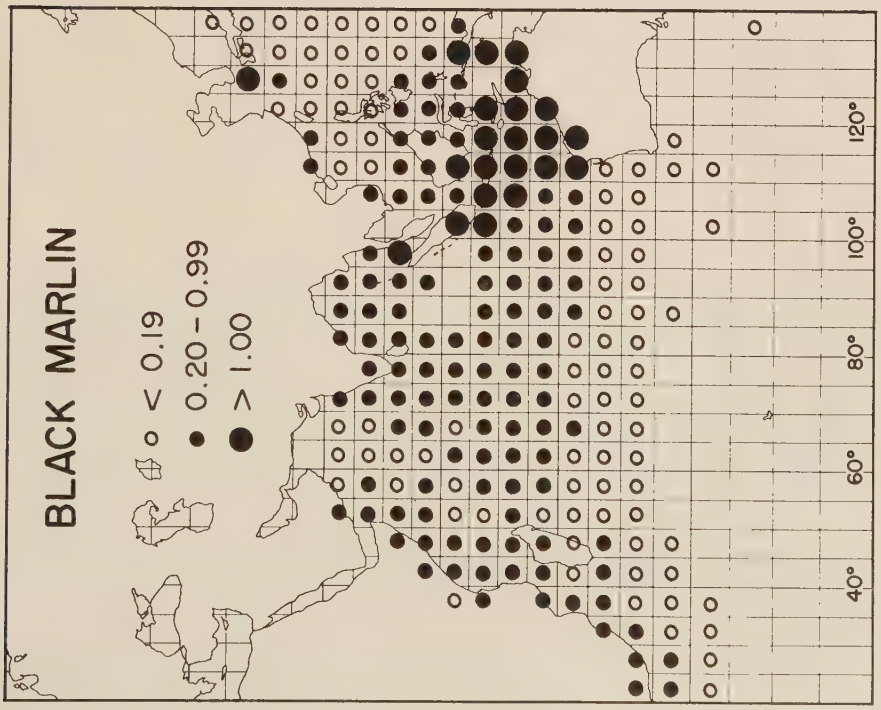


Figure 39. Continued

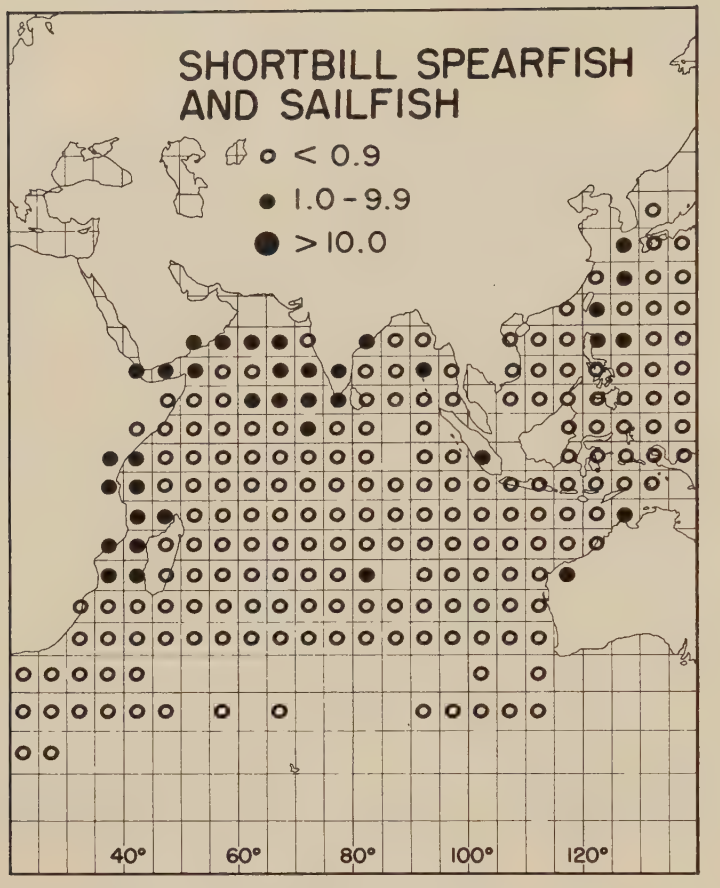


Figure 39. Continued

3.10.2 Review of fishery data

3.10.2.1 Total catch and effort trends

In the Indian Ocean almost the entire billfish catch is harvested incidentally by tuna longliners of Japan, Taiwan, and Korea. In the case of Japan and Taiwan, the recorded total catch statistics for blue marlin, black marlin, striped marlin, and swordfish are relatively reliable, but catches of sailfish and shortbill spearfish are combined. There has also been some combined reporting of blue marlin and black marlin. In the case of Korea, catches of billfishes were not separated by species prior to 1975. Although significant improvement in Korean reporting practices have taken place in recent years, there apparently may still be some misreporting since FAO statistics show no catch of black marlin by Korea in the Indian Ocean.

In addition to the longline catch by Japan, Taiwan, and Korea, there is a small catch of billfishes by Indonesian vessels and by sport fishermen in South Africa, Kenya, Seychelles, and Western Australia.

Because the historical record of billfish catches in the Indian Ocean is so incomplete, it is not possible to draw very useful conclusions about trends in the aggregate catch. However, the catches by Japan and Taiwan for most species reached high levels in the late 1960's, and declined thereafter (Table 17), due in part to a shift of longline effort southward into areas of relatively low billfish abundance.

TABLE 17. Catch of billfishes (metric tons) by species in the Indian Ocean (from SAWS/BP/20)

Year	Swordfish		Striped marlin		Blue marlin		Black marlin		Sailfish and spearfish	
	Japan	Taiwan	Japan	Taiwan	Japan	Taiwan	Japan	Taiwan	Japan	Taiwan
1952	<100		100		800		300		<100	
1953	100		300		2,000		800		100	
1954	200		800		3,300		1,100		200	
1955	200		800		3,600	100	1,100	100	200	
1956	500		1,800		5,000	200	1,500	200	300	
1957	300	100	1,800	100	3,800	100	1,400	400	300	
1958	500	100	1,700	200	4,100	200	1,200	500	400	100
1959	500	100	2,100	400	4,300	300	1,200	500	500	300
1960	600	100	2,000	300	3,700	300	1,700	300	500	200
1961	700	200	2,400	300	3,200	300	1,400	500	500	100
1962	900	200	1,800	200	3,100	400	1,800	300	800	200
1963	700	[1]300	1,300	[1]500	1,800	[1]500	1,100	[1]400	500	[1]300
1964	900	[1]300	1,400	[1]600	2,900	[1]600	1,300	[1]400	600	[1]300
1965	1,100	[1]200	3,000	[1]400	3,300	[1]400	1,100	[1]300	1,100	[1]200
1966	1,200	[1]200	3,900	[1]300	3,300	[1]300	1,200	[1]200	1,200	[1]200
1967	1,600	200	4,200	300	3,400	700	1,300	200	1,900	100
1968	1,200	600	2,300	900	2,300	1,400	1,700	600	1,200	400
1969	1,200	800	2,200	1,800	1,800	1,500	1,300	800	700	400
1970	1,000	800	1,700	900	1,200	1,200	900	600	600	300
1971	800	500	1,000	700	1,000	1,000	700	500	800	400
1972	800	400	800	400	900	800	200	400	600	300
1973	500	300	500	300	600	500	200	200	300	100
1974	600	400	1,400	500	900	500	400	300	300	100
1975	700	300	900	300	700	400	500	200	200	500
1976	300	400	500	800	300	300	200	100	200	300
1977	300	400	500	1,400	300	500	100	100	<100	<100

[1]Roughly estimated from the annual total catch.

As with total catch data, detailed effort statistics are not available for Korean longliners, so no complete picture of trends in total effort can be drawn.

3.10.2.2 Trends in catch per unit effort

Average catch rate statistics are available for both Japan and Taiwan. A decline in CPUE over the 1952-76 period occurred in the Japanese longline fishery for blue marlin (Figure 40), striped marlin (Figure 41), and with considerable fluctuation, black marlin (Figure 42). Swordfish CPUE has not declined significantly (Figure 43). Catch rates for sailfish (small amounts of spearfish are included) are quite variable but a general increase over the 1952-76 period is evident (Figure 44).

3.10.3 Stock structure

Available information on geographical variation in catch rates and spawning area suggests a single stock of blue marlin in the Indian Ocean. Similar kinds of data suggest the possibility of multiple stocks for striped marlin, black marlin, swordfish, and sailfish, but there is little solid data to support either single or multiple stock hypotheses. In the case of black marlin, there may be some interaction between fish in the eastern Indian

Ocean and those in the southwestern Pacific, but to date no black marlin tagged off Cairns (northeast coast of Australia) have been recaptured west of Cape York Peninsula, Australia.

3.10.4 Population parameters

No estimates of growth rates, mortality rates or recruitment for Indian Ocean billfishes are available. However, studies have been undertaken on maturation and spawning of striped marlin, which suggest this species attains sexual maturity at 140-150 cm (eye-fork length).

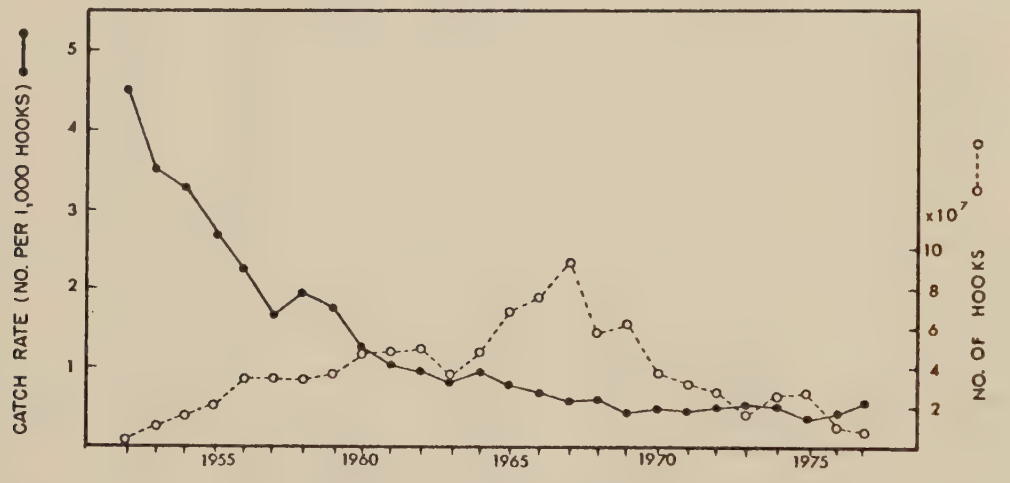


Figure 40. Catch rates and effective fishing effort for blue marlin in the Indian Ocean (from SAWS/BP/20)

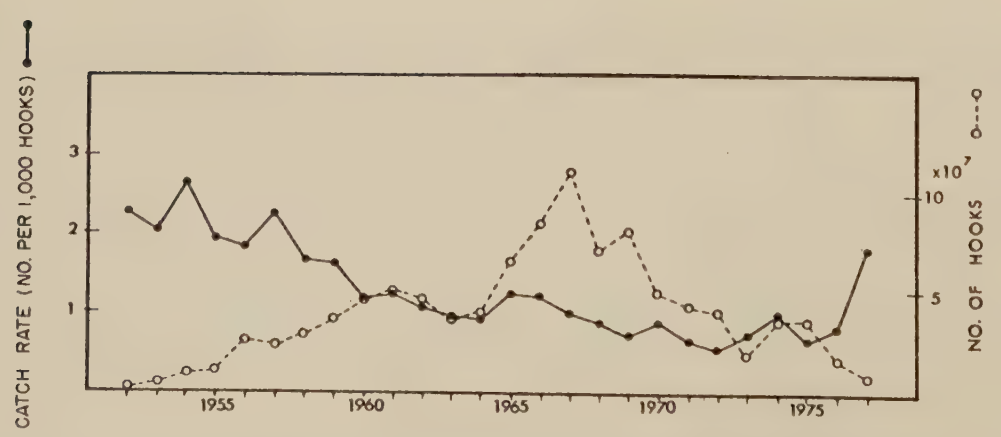


Figure 41. Catch rates and effective fishing effort for striped marlin in the Indian Ocean (from SAWS/BP/20)

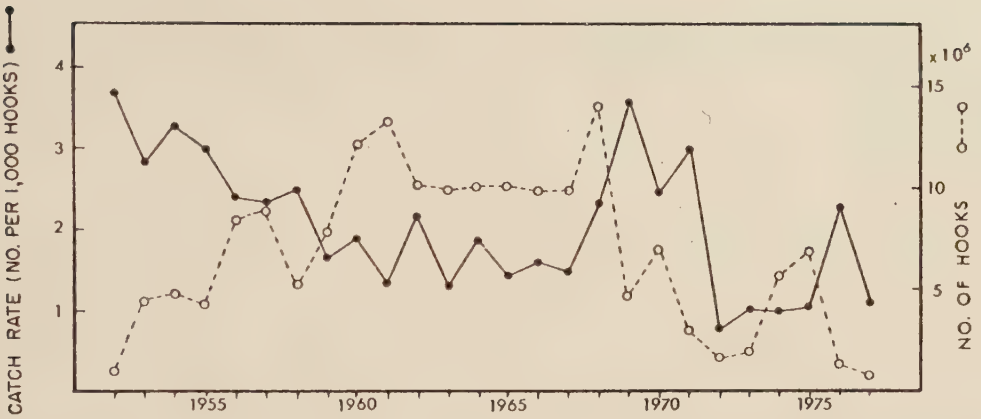


Figure 42. Catch rates and fishing effort for black marlin in the eastern Indian Ocean (lat. 0°-20°S, long. 100°-125°E) (from SAWS/BP/20)

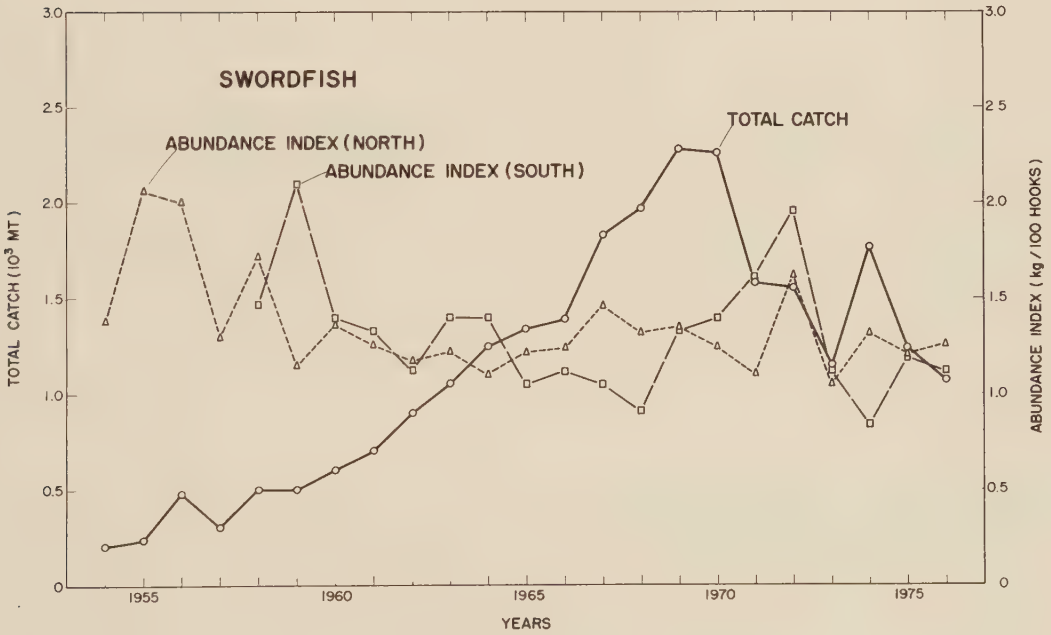


Figure 43. Estimated total catch (10^3 MT) and relative abundance (kg/100 hooks) for Indian Ocean swordfish. Abundance indices are given for two index areas (from SAWS/BP/21)

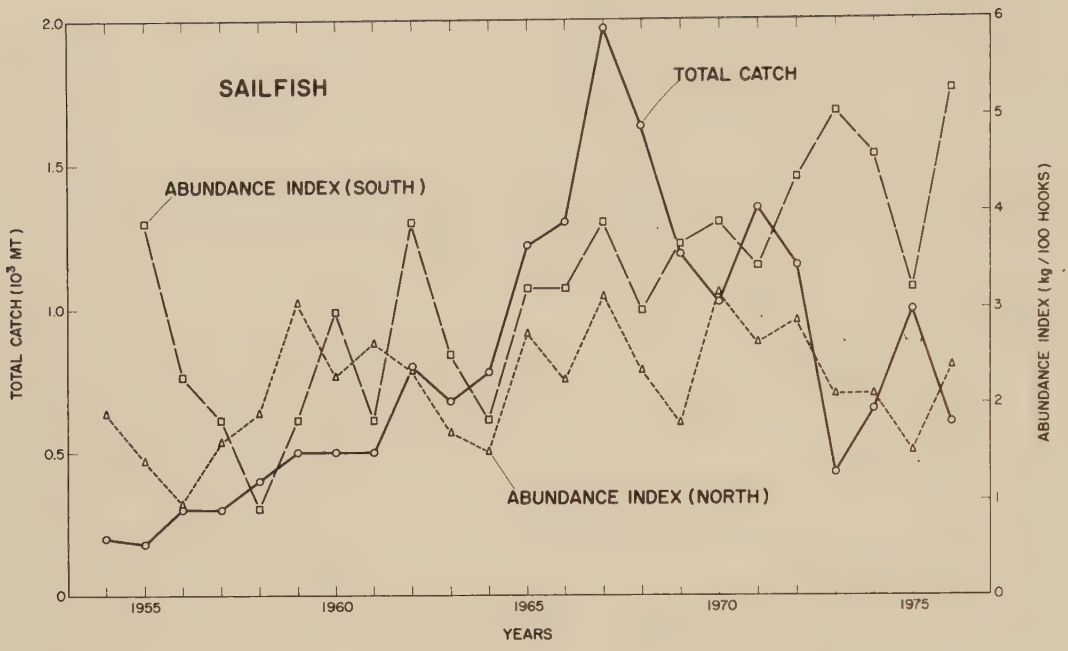


Figure 44. Estimated total catch (10^3 MT) and relative abundance (kg/100 hooks) for Indian Ocean sailfish. Abundance indices are given for two index areas (from SAWS/BP/21)

3.10.5 Status of stocks

Deficiencies in estimates of total catch for Indian Ocean billfishes make reliable assessment of potential yields and optimum fishing effort impossible. However, the substantial reduction in catch rates for blue marlin and black marlin since the inception of longlining suggests that no significant increases in total yield can be expected for these species. The potential for an increased yield of striped marlin seems to be somewhat greater. Stocks of swordfish and sailfish do not appear to have been affected appreciably by the effort exerted to date.

No firm conclusions can be drawn for any species without better catch statistics.

3.10.6 Recommendations

Reliable assessment of the status of Indian Ocean billfishes will require considerable improvements in fishery statistics. In particular, steps should be taken to correct deficiencies in identification of species and to allow for the separate recording of the catch of each species in longline logbook records. To the extent practicable, billfish landings should be recorded by species.

3.11 General Problems in Stock Assessment (Rapporteurs: John A. Gulland and Robert A. Skillman)

When discussing the individual stocks a number of similar problems were raised. Some of the more striking of these common problems, and suggestions for ways in which they may be tackled, are as follows.

3.11.1 Effort

The discussions on the problems in accurately determining effort and CPUE in the workshop were based almost exclusively on longline data. There were also problems in determining the correct measure of effort in most surface fisheries. It was noted that where there have been successful tagging experiments, especially over a period of years, the rate of return of tags per unit fishing effort can in principle be used to calibrate the fishing effort data. This might well be possible for the Australian southern bluefin tuna fishery. To allow for adequate mixing of tagged fish in the fishery, it was suggested that return information for fish tagged as 2- or 3-yr olds should be used from the second and subsequent years after release.

In the longline fishery four points were examined: (1) the use of deep longlines; (2) change in preferred (target) species or area; (3) the interpretation of CPUE statistics at high stock densities in the beginning of a fishery; and (4) possible gear competition or interference at high fishing intensities.

The use of deep longlines (normal longlines made to fish deeper by essentially omitting every second float) definitely increases the catch rate of bigeye tuna in many areas. The proportion of deep longlines used in a fishery was estimated from the frequency distribution of longline gear by number of hooks per basket (see Figure 15). The increase in efficiency for bigeye tuna has been estimated as 1.78 for the western equatorial Pacific, but is believed to vary from area to area according to the depth of the thermocline (Table 18). Nominal effort data can then be corrected by using the efficiency factor and the percentage of deep longline gear. The workshop participants felt that more studies on this would be desirable, especially to estimate directly the efficiency factors for the Indian Ocean, and also the possible effects on the catches of other species.

TABLE 18. Correction factors to adjust for changes in efficiency of longline gear for capture of bigeye tuna and the percentage of deep longline gear used in the Japanese longline fishery in terms of trips and major areas of the equatorial Pacific (preliminary) (from SAWS/BP/6)

	Western equatorial area (west of 170°E)	Central equatorial area (170°E-150°W)	Eastern equatorial area (east of 150°W)
1975	50%	20%	10%
1976	60%	25%	35%
1977	70%	45%	65%
Correction factor	1.7	1.5	1.3

Methods to correct for shifts in area or target species are well established (e.g., Honma, 1974) and the participants felt that, provided the data were well spread over the ocean, these methods worked well. Since the Japanese fleet is now mainly concentrated in a few fishing areas (e.g., those for southern bluefin tuna) there is an urgent need to obtain and use the detailed 5° square data from the other longline fleets.

Problems in using catch rate statistics to index the abundance of a stock during the early years of a fishery were discussed. In several cases examined by the group, the differences between catch rates recorded in the first few years of fishing and those observed several years later were perhaps greater than expected. For example, in the case of Indian

Ocean yellowfin tuna the CPUE, when plotted against average effort, dropped from nearly 175 kg/100 hooks at the beginning of the fishery to less than 25 kg/100 hooks in recent years (Figure 45). If CPUE is assumed to be proportional to abundance, then a reduction of the exploitable yellowfin tuna stock to roughly 10-15% of the stock size before fishing commenced is suggested. This is such a large drop that a failure of the proportionality assumption is suspected. In particular, the ratio of CPUE to stock size may have been greater in the early years than later on, because the developing fishery may have concentrated effort in areas with exceptionally high catch rates, and not fished at all over much of the stock's range where catch rates would have been lower. Adjustment procedures commonly used to correct for temporal changes in effort distribution may not be effective in such situations. One possible remedy is to simply omit some of the early CPUE data from stock assessment analyses (such as production model analyses). In the case of Indian Ocean yellowfin tuna, the true relationship between stock size and effort probably lies somewhere in-between the dashed and solid curves of Figure 45.

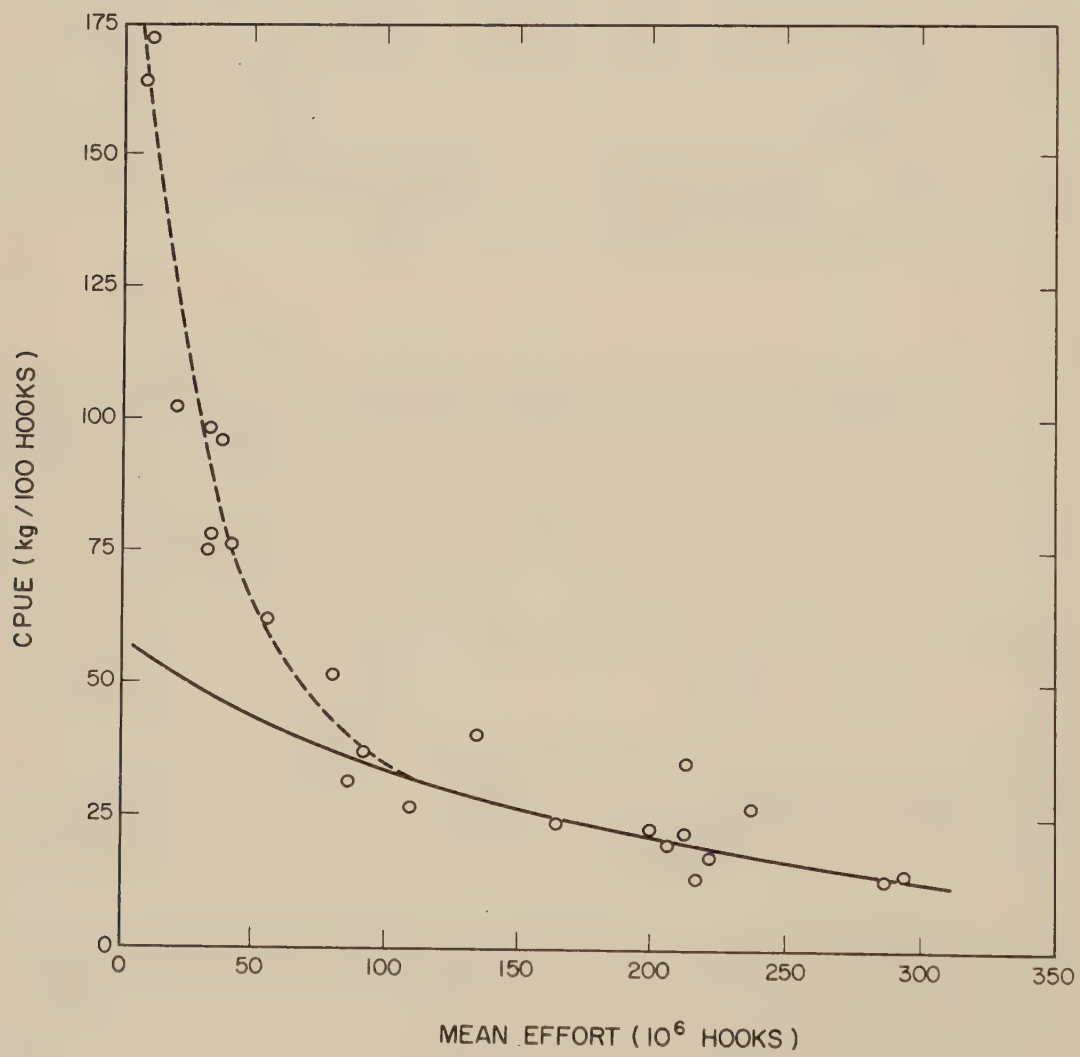


Figure 45. Relation between CPUE (kg/100 hooks) for yellowfin tuna and mean effort (number of hooks) in the Indian Ocean. Mean effort statistics for a given year was computed by averaging the actual effort for that year and for the immediately preceding year

The problem of interference or gear competition between vessels at high effort concentrations raises other questions. It was suggested that the reason for the remarkably small change in total longline catch over a wide range of effort for some stocks (e.g., Indian Ocean yellowfin tuna) was that the true fishing mortality changed much less than the nominal effort. This change in fishing mortality would occur if the effectiveness of a given number of hooks was reduced where fishing was intense. The workshop saw no way of testing this hypothesis immediately, though it is a question of some importance. One possible approach would be to examine detailed data on catch rates from logbooks of vessels fishing at the center, and at the fringes, of major concentrations of fishing effort. Such a study would require a careful examination of the distribution of catches and the indices of concentration.

3.11.2 Age, growth, and mortality

In the absence of reliable methods of aging individual tuna, age-growth and mortality parameters are not readily available. The implications of this lack of information depend on the intended use of the information.

The workshop noted that there were difficulties in estimating age composition, particularly at older ages, from length-composition data, either using an age-length key in the strict sense (i.e., estimates of the percentage of each age in a length class), or by direct dissection of the length data (e.g., assigning all fish between 105 and 112 cm to a certain age). Age compositions from both methods are likely to lead to underestimation of the changes in mortality that occur, unless a separate age-length key is computed for each period in which a change in mortality occurs. The workshop therefore urged that a careful examination should be made of the theoretical problems involved.

The pattern of recaptures of tagged southern bluefin tuna in the longline fishery shows that the mortality in this fishery is low, and that previous estimates of the ages of large fish were too low. The group believed that the phenomenon of low total and natural mortality among large fish and a higher natural mortality among smaller fish may be quite general among tunas, even though the direct evidence is slight. It should certainly be taken into account when assessing the impact of surface fisheries on longline fisheries.

There had been a number of advances in methodology for aging tuna (burning or sectioning otoliths, counting of daily rings) and the group encouraged the continuation of this work. It was felt at the workshop that efforts for aging tunas should be concentrated on a few stocks that seem to offer more favorable opportunities, e.g., stocks from which material would be regularly available, and in which data could be cross-checked by methods such as tagging. The southern bluefin tuna, which may show clear annual marks, would be one possibility.

3.11.3 Assessment of the effect of fishing

The assessment of fishing effects was mainly done by examining the relationship between catch and effort and fitting production models to these data from the longline fisheries. It was considered desirable to obtain independent evidence of the effect of fishing on the stocks, such as changes in total mortality. Without good age data this is difficult to do. The results presented for Indian Ocean yellowfin tuna (Figure 46) showed an apparent increase in the coefficients of total mortality with increasing fishing intensity. Though some participants thought that the method of estimating ages would introduce a bias, the nature of this bias would be to underestimate the changes in mortality rates. The fact that some change in mortality coefficients was readily apparent in this stock and in others (e.g., Indian Ocean bigeye tuna, Figure 47), even though there were possible biases underestimating the change, suggests that the real change in mortality may have been considerable. A crude estimate of changes in mortality coefficients can be obtained by looking at changes in average size. In nearly all longline fisheries, average size of fish has decreased in close correlation with increased fishing effort (Figure 48). There are obvious dangers that some of such changes could be due to changes in the area of fishing, especially for albacore and bigeye tuna. The workshop recommended that this question should be more

carefully examined. A study should be undertaken to analyze changes in size composition within small areas, and to determine better theoretical procedures for estimating changes in total mortality from changes in length composition.

The problem of estimating the impact of surface fisheries on longline fisheries is even greater (SAWS/BP/4). Factors which affect the impact are: (1) the relative size of fish taken by the two gears; (2) variability in natural mortality; (3) the difference in "stocks" or groups of fish exploited by the two fisheries; and (4) differences in time/area strata in which the fish are exploited by the two fisheries.

In some cases where there is interaction, it is masked because the two fisheries operate in different areas or on fish of substantially different size. It was noted that the effect of the surface yellowfin tuna fishery on the longline fishery in parts of the central and eastern Pacific seemed to become noticeable after the expansion of the surface fishery offshore where larger fish occur. The relative importance of these two factors is unknown.

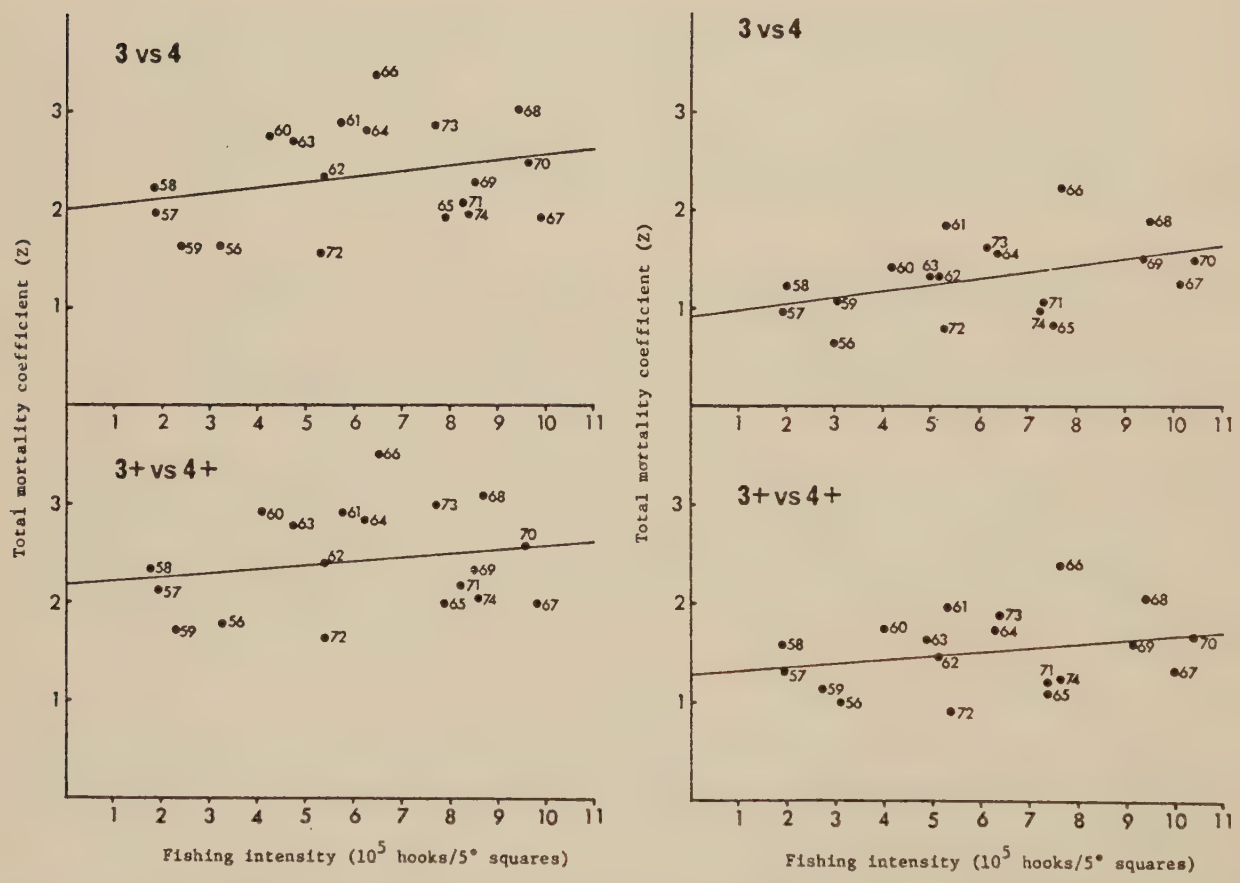


Figure 46. Relationship between fishing intensity and annual total mortality coefficient for age 3 yellowfin tuna (upper panels) and age 3 and older yellowfin tuna (lower panels) on the basis of the age-length keys by Huang et al. (1973) (left panels) and by Yabuta et al. (1960) (right panels). Numerals in the figure denote years (from SAWS/BP/17)

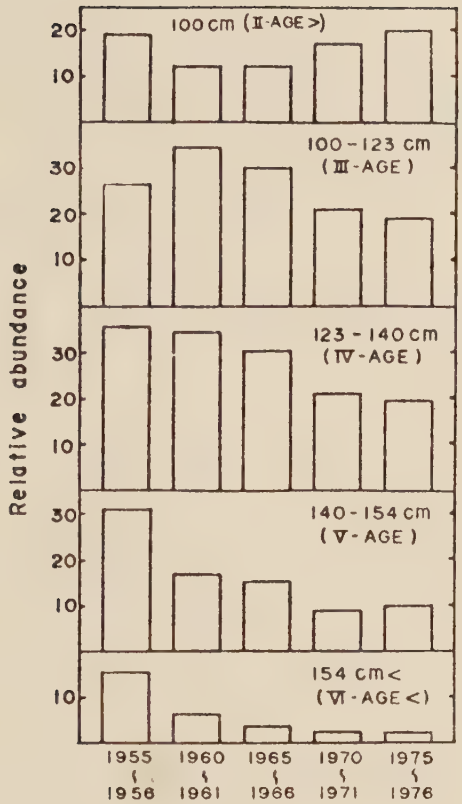


Figure 47. Relative abundance of bigeye tuna, by age, in the Indian Ocean (excluding Banda Sea) (from SAWS/BP/18)

Few explicit Y/R calculations were presented. In the absence of reliable estimates of growth and mortality a single Y/R curve is of doubtful value. Nevertheless the workshop recommended an examination of a set of Y/R curves, for different values of input parameters, including higher values of natural mortality for small fish (i.e., those in some surface fisheries) than for large fish. This analysis could be useful in elucidating the likely response of the stocks to different patterns of fishing, including the interaction between surface and longline fishing. Such calculations could assist in determining whether the observed approximately constant catch over a wide range of effort, as seen in several long-line fisheries, is reasonable, or is due to an artifact, such as gear competition.

Several papers discussed stock recruitment relationships. Over the range of abundance so far experienced, no large variation in recruitment with stock size has been found. This is consistent with the high individual fecundity of tunas. However, in view of the serious consequences if recruitment is impaired, and the increased possibility of this occurring with very high levels of effort, the matter deserves careful attention. In particular, a series of recruitment estimates--e.g., from CPUE of young fish, or from cohort analysis--should be obtained for all the major stocks.

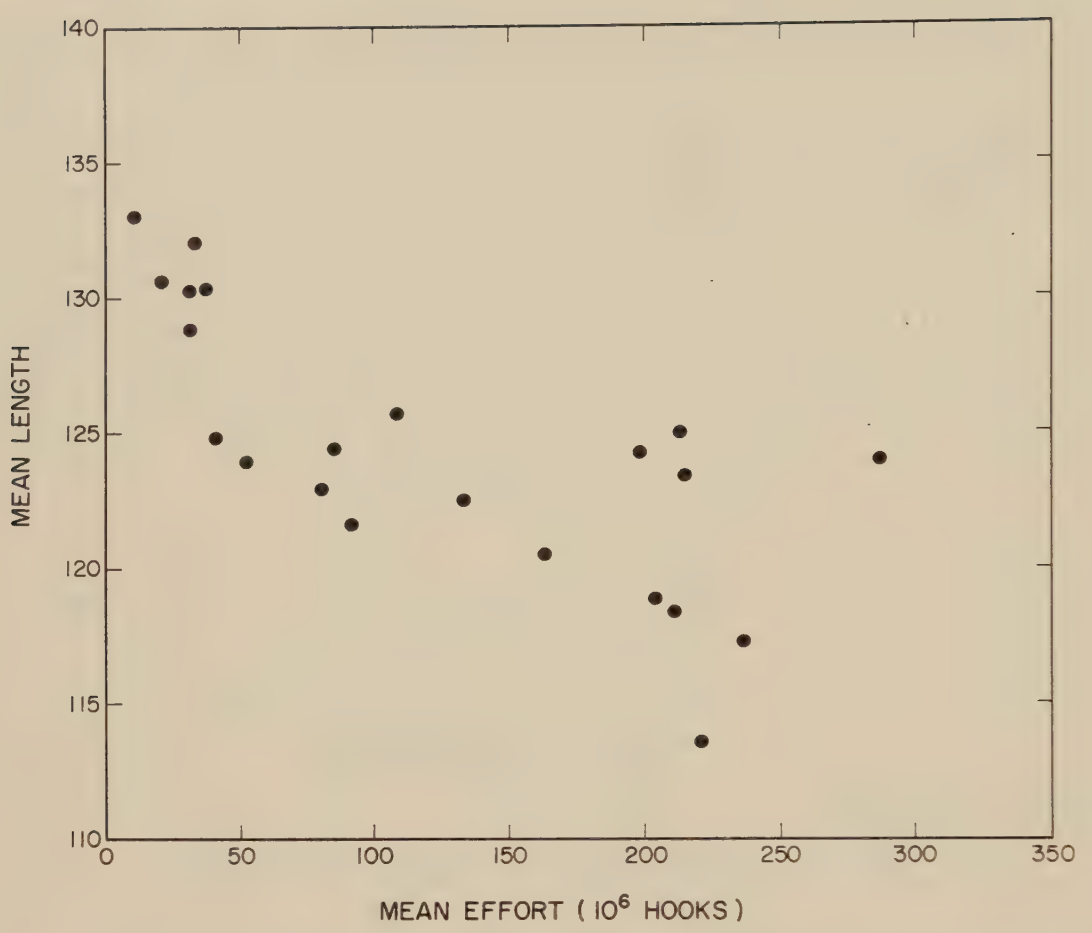


Figure 48. Relation between mean length of yellowfin tuna and mean fishing effort in the Indian Ocean

4. LITERATURE CITED

Food and Agriculture Organization of the United Nations, Catches and landings, 1973. FAO 1974a Yearb.Fish.Statist., (36):590 p.

_____, Report of the Second Session of the IPFC/IOFC Ad Hoc Working Party of 1974b Scientists on Stock Assessment of Tuna, Nantes, France, 16-18 September 1974. FAO Fish.Rep., (152):19 p.

_____, Report of the Third Joint Meeting of the Indo-Pacific Fisheries Council, 1975 Special Committee on Management of Indo-Pacific Tuna, Third Session, and the Indian Ocean Fishery Commission, Committee on Management of Indian Ocean Tuna, Fourth Session, Mombasa, Kenya, 18-19 July 1975. FAO Fish.Rep., (174):47 p.

_____, Catches and landings, 1975. FAO Yearb.Fish.Statist., (40):417 p. 1976

_____, Catches and landings, 1976. FAO Yearb.Fish.Statist., (42):323 p. 1977

_____, Catches and landings, 1977. FAO Yearb.Fish.Statist., (44):343 p. 1978

Honma, M., 1974 Estimation of overall effective fishing intensity of tuna longline fishery. Bull.Far Seas Fish.Res.Lab.(Shimizu), 10:63-85

Huang, C.-C., L. Sun and R.-T. Yang, 1973 Age, growth and population structure of the Indian yellowfin tuna. [In Chin., Engl. abstr.] J.Fish.Soc.Taiwan, 2(1):16-30

Inter-American Tropical Tuna Commission, 1979 Annual report of the Inter-American Tropical Tuna Commission, 1978:163 p.

Koto, T., 1969 Studies on the albacore--XIV. Distribution and movement of the albacore in the Indian and the Atlantic Oceans based on the catch statistics of Japanese tuna long-line fishery. [In Jpn., Engl. summ.] Bull.Far Seas Fish.Res.Lab. (Shimizu), 1:115-129

Morita, Y., 1973 Conversion factors for estimating live weight from gilled-and-gutted weight of bigeye and yellowfin tunas. [In Jpn., Engl. summ.] Bull.Far Seas Fish.Res. Lab.(Shimizu), 9:109-121

Morita, Y. and T. Koto, 1971 Some consideration on the population structure of yellowfin tuna in the Indian Ocean based on the longline fishery data. [In Jpn., Engl. summ.] Bull.Far Seas Fish.Res.Lab.(Shimizu), 4:125-140

Nakamura, I., T. Iwai and K. Matsubara, 1968 A review of the sailfish, spearfish, marlin and swordfish of the world. [In Jpn.] Misaki Mar.Biol.Inst., Kyoto Univ.Spec.Rep. (4):1-95

Shomura, R.S. (Ed.), 1980 Summary report of the Billfish Stock Assessment Workshop, Pacific Resources. NOAA Tech.Memo.NMFS-SWFC-5, 58 p.

Yabuta, Y., M. Yukinawa and Y. Warashina, 1960 Growth and age of yellowfin tuna, II. Age determination (scale method). Rep.Nankai Reg.Fish.Res.Lab.(Kochi), 12:63-74

APPENDIX 1

AGENDA

13 June

Opening of session
Adoption of agenda

14 June

General discussion of data base, review of catch statistics
Stock assessment of Pacific yellowfin tuna and northern bluefin tuna

15 June

Stock assessment of Pacific bigeye tuna
Stock assessment of South Pacific albacore

16 June

Stock assessment of southern bluefin tuna

17 June

Excursion

18 June

Stock assessment of Indian Ocean yellowfin tuna
Stock assessment of Indian Ocean bigeye tuna and albacore

19 June

Stock assessment of Indian Ocean billfishes
Consideration of special problems in stock assessment

20 June

Continuation

21 June

Write-up of summary report

22 June

Review and approval of summary report

APPENDIX 2

LIST OF PARTICIPANTS

Dr. Norman W. Bartoo
Southwest Fisheries Center
National Marine Fisheries Service
P. O. Box 271
La Jolla, California 92038

Dr. John A. Gulland
FAO of the United Nations
Via delle Terme di Caracalla
00100 Rome, Italy

Mr. Misao Honma
Far Seas Fisheries Research Laboratory
1000 Orido, Shimizu 424
Shizuoka, Japan

Dr. James Joseph
Inter-American Tropical Tuna Commission
c/o Scripps Institution of Oceanography
La Jolla, California 92037

Dr. Robert E. Kearney
South Pacific Commission
B. P. D5
Noumea Cedex, New Caledonia

Dr. Shoji Kikawa
Far Seas Fisheries Research Laboratory
1000 Orido, Shimizu 424
Shizuoka, Japan

Dr. Bong Yeoul Kim
Fisheries Research and Development Agency
#16, 2nd-Ga, Namhang-Dong, Yeongdo-Gu
Pusan 606, Republic of Korea

Mr. Susumu Kume
Far Seas Fisheries Research Laboratory
1000 Orido, Shimizu 424
Shizuoka, Japan

Dr. Peter M. Miyake
International Commission for the
Conservation of Atlantic Tunas
General Mola
17 Madrid-1, Spain

Dr. Garth I. Murphy
Commonwealth Scientific and Industrial
Research Organization
P. O. Box 21
Cronulla, New South Wales, Australia

Dr. Gary T. Sakagawa
Southwest Fisheries Center
National Marine Fisheries Service
P. O. Box 271
La Jolla, California 92038

Mr. Chiomi Shingu
Far Seas Fisheries Research Laboratory
1000 Orido, Shimizu 424
Shizuoka, Japan

Mr. Richard S. Shomura
Southwest Fisheries Center
National Marine Fisheries Service
P. O. Box 3830
Honolulu, Hawaii 96812

Dr. Robert A. Skillman
South China Sea Fisheries Development
and Coordinating Programme
P. O. Box 1184, M.C.C.
Makati, Metro Manila, Philippines

Mr. Ziro Suzuki
Far Seas Fisheries Research Laboratory
1000 Orido, Shimizu 424
Shizuoka, Japan

Dr. Shoji Ueyanagi
Far Seas Fisheries Research Laboratory
1000 Orido, Shimizu 424
Shizuoka, Japan

Dr. Jerry A. Wetherall
Southwest Fisheries Center
National Marine Fisheries Service
P. O. Box 3830
Honolulu, Hawaii 96812

Dr. Rong-Tszong Yang
National Taiwan University
Institute of Oceanography
P. O. Box 23-13
Taipei, Taiwan

APPENDIX 3

RAPPORTEURS

J.A. Gulland and R.A. Skillman
Statistics and other data

N.W. Bartoo and Z. Suzuki
Pacific yellowfin tuna

R.A. Skillman and C. Shingu
Pacific northern bluefin tuna

R.E. Kearney and S. Kume
Pacific bigeye tuna

G.T. Sakagawa and B.Y. Kim
South Pacific albacore

R.A. Skillman and C. Shingu
Southern bluefin tuna

P.M. Miyake and Z. Suzuki
Indian Ocean yellowfin tuna

R.E. Kearney and S. Kume
Indian Ocean bigeye tuna

G.I. Murphy and R.-T. Yang
Indian Ocean albacore

J.A. Wetherall and S. Kikawa
Indian Ocean billfishes

J.A. Gulland and R.A. Skillman
General problems in stock assessment

APPENDIX 4

LIST OF BACKGROUND PAPERS

SAWS/BP/ 1 Yoshida, H.O.
Compilation of published estimates of tuna life history and population dynamics parameters.

2 Honma, H. and Z. Suzuki
Stock assessment of Pacific yellowfin tuna exploited by the tuna longline fishery together with surface and other fisheries in the western and central Pacific.

3 Suzuki, Z., P.K. Tomlinson and M. Honma
Population structure of Pacific yellowfin tuna. Inter-Am. Trop. Tuna Comm. Bull. 17:277-441, 1978.

4 Lenarz, W.H. and J.R. Zweifel
A theoretical examination of some aspects of the interaction between longline and surface fisheries for yellowfin tuna, Thunnus albacares. Fish. Bull., U.S. 76:807-825, 1979.

5 Inter-American Tropical Tuna Commission
Assessment studies of yellowfin tuna in the eastern Pacific Ocean.

6 Kume, S.
Bigeye tuna resource in the Pacific Ocean, its fishery biology and a status of the stock.

7 Wetherall, J.A.
Report of the Third North Pacific Albacore Workshop, Honolulu, Hawaii, 13-14 September 1978.

8 Wetherall, J.A., F.V. Riggs and M.Y.Y. Yong
Assessment of the South Pacific albacore stock.

9 Bayliff, W.H. and H.P. Calkins
Information pertinent to stock assessment of northern bluefin tuna, Thunnus thynnus, in the Pacific Ocean.

10 Hisada, K., C. Shingu and T. Yonemori
The bluefin fisheries in the northwestern Pacific and biological information obtained from them.

11 Shingu, C. and K. Hisada
Recent status of the southern bluefin tuna stock.

12 Murphy, G.I.
Situation report - Southern bluefin tuna.

13 Murphy, G.I. and H. Sutherland
Mortality rates in the southern bluefin tuna, Thunnus maccoyii (Castelnau).

14 Hearn, W.S.
Growth of southern bluefin tuna (Thunnus maccoyii)

15 Kirkwood, G.P.
Estimation of rates of tag shedding by southern bluefin tuna (Thunnus maccoyii)

M-43
ISBN 92-5-101003-X